HOW TO SELECT AN INDIRECT THERMAL TECHNOLOGY FOR INDUSTRIAL MATERIALS PROCESSING

Better Thermal Processing Results Begin with Selecting the Right Technology

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For materials that need to be heated, cooled or dried, you may be considering using indirect thermal processing – the conductive thermal treatment of a material that is isolated from the heating/cooling media by a vessel wall. Perhaps you have limited space available, or you need to mechanically convey the material over a short distance, or you want to limit the amount of air-handling equipment and auxiliaries in your process. So which indirect thermal technology is right for your material?

Nearly every industrially processed material, or a byproduct of production, needs to be heated or cooled at some point. By using indirect thermal processing, you can often increase the value of your final product and/or eliminate material handling issues.

For example, by reducing the moisture content of waste slurries through indirect drying, you can reduce transport and disposal costs, as well as environmental impact. And some waste streams contain valuable byproducts that, when recovered through indirect thermal treatment, can provide an added revenue stream. Heat treatment of food and feed products can increase product shelf life and eliminate microbiological issues. On the other hand, materials coming out of high temperature processing steps can be cooled for storage, blending or final packaging.

In this white paper, we review the basics of indirect thermal processing, examine different types of indirect thermal processing technologies, and suggest optimal technologies for various materials and processes. While there are several indirect thermal technologies available, this paper covers the most common. Through this paper, you should be better equipped to match the right technology to your specific material processing needs.

**Indirect Thermal Processing – The Basics**

Indirect processes rely on heat transfer media, such as hot oil, steam, or water, which is isolated from the treated material by a metal surface. In other words, the material itself never comes into direct contact with the heat transfer media. Through mechanical agitation, the material to be treated travels past the metal surface and onward to the next process step.

By comparison, direct thermal processes typically mix heated or ambient gas 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. Direct treatment usually requires a larger system with multiple components, leading to increased plant investment and space issues. 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.

The advantages and disadvantages of indirect thermal processing are detailed on following page.
Indirect Thermal Processing Advantages

Separation of the material from the heat transfer media protects against product contamination. Since gas, such as air or nitrogen, is not the primary thermal medium, little or no process gas is required. This eliminates the need for emissions treatment and reduces the environmental impact of your plant. This also means that auxiliary equipment, such as blowers and dust collectors, are not required, lowering your capital costs and space requirements. Overall, these factors reduce your installed costs.

High thermal efficiency means more of the energy is transferred into the material rather than being exhausted into the surrounding area. Because the heat transfer fluids are contained within a closed-loop system, it can be circulated back through the heating process; the energy required to keep the media at temperature can be reduced. In single-pass systems, where the heat transfer media is not recirculated, a heat exchanger can be employed to provide a low-cost method of energy recovery for heating or cooling other areas of your plant or process.

Mechanical agitation prevents undesirable agglomeration, but is gentle enough to maintain particle size. This same agitation provides an effective method for mixing wet and/or dry ingredients into the final product formulation. Since the agitation serves to keep the material moving, rather than exerting a lot of force on the material, mechanical wear is minimized or non-existent. This limits maintenance costs to normal mechanical service items (bearings, belts, seals, etc.).

Lastly, these processes provide significant flexibility. Nearly all indirect technologies can operate in continuous or batch modes, giving you ultimate control over the final product. Inerting gas can be employed for hazard protection and improved product functionality; by adding nitrogen or dry air in the process you can reduce condensation and, in drying, remove more moisture. The amount of gas required is small enough that it can be recirculated into the process with little additional investment.

Indirect Thermal Processing Disadvantages

There are a few limits to indirect thermal processing. On the process side, solids in solutions cannot be dried, because they change physical and chemical properties when dissolved in a solvent. Sticky materials will coat the heat transfer surfaces, effectively insulating the process and reducing the ability for the heat transfer media to act on the material.

Mechanically, physical machine constraints can limit scale-up flexibility. While gentle, the mechanical design will sometimes input energy into the product, thus increasing your thermal load. Capital equipment costs can be higher than direct thermal processing.
Types and Benefits of Indirect Thermal Processing Technologies

The most common technologies for indirect thermal processing are described below. Please note that while the term “dryer,” below, is often used to describe a technology, it is not limited to drying alone.

Hollow-flight screw conveyors (Figure 1) use a traditional screw conveyor body design with a hollow screw containing the heat transfer fluid. The material to be treated is fed in one end of the machine, typically through a port in the top. It then travels horizontally and is discharged out the bottom at the opposite end. A jacketed body can be incorporated into the design, which can then be filled with heat transfer media, making the vessel wall itself a thermal source for heat transfer.

Hollow-flight screw conveyors provide some of the highest residence times in continuous applications for materials requiring lengthy processing (45-60 minutes or more). The slow, smooth movement of the rotor keeps the material from mixing and maintains even, uniform transport (plug flow) through the vessel. The result is a gentle process that provides strict control of the material’s residence time.

However, this same mechanism also means there is no change of material at the heat transfer surface. This translates to temperature gradients across the material between the screw flights, causing uneven treatment of the material, and some of the lowest thermal efficiencies in indirect processing. Lastly, slurry and highly liquid materials can leak through the gap between the screw and the vessel wall, causing the material to bypass most of the heat transfer area, resulting in poor treatment.

Thin film dryers (Figure 2) rely on a rotor inside a cylindrical vessel operating at high tip speeds (1,000-3,000 feet per minute) that force the material into a thin layer along a cylindrical vessel wall which contains the heat transfer fluid. These are most commonly horizontal devices, but they can also be found in vertical configurations. Here, the wall contains a hollow jacket that provides the entire heat transfer surface. The rotor consists of flat paddles installed vertically along its length that angle to control the conveyance and residence time of the material. Not to be confused with a paddle dryer, the paddles in a thin film 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 through a port in the bottom on the opposite end. This type of dryer is limited to continuous processes only.

Figure 1: The Bepex Themascrew® is a single or twin-screw conveyor with heated screw(s) and jacketed body. Material is conveyed in a plug flow fashion. Gentle action of the screws minimizes particle size reduction.
Thin film dryers have the greatest 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. Multiple feeding options, including pumping and spraying into the vessel, make this option suitable for nearly every feed consistency. The dryer’s short residence times allow for strict control of the material temperature, making it ideal for temperature-sensitive feeds.

In drying applications, thin film dryers are not as effective in processing materials that are difficult to dry or require longer residence times. Materials that require heating or cooling very close to the heat transfer fluid temperature will typically require additional operations, where more time is necessary to get the product to temperature. This is usually accomplished using a heated holding vessel with mechanical agitation, such as a blender or hollow-flight screw conveyor.

Paddle dryers (Figure 3) are designed to operate much like the previously mentioned screw conveyors, but the rotor assembly instead consists of a series of hollow discs or “paddles” mounted horizontally along a center pipe inside the vessel. The rotor pipe provides mechanical support and an external port for the heat transfer media to enter and exit. The rotor mixes and conveys the material to the opposite end of the machine, where it is discharged through a port in the bottom or in the side of the vessel.

Paddle dryers deliver the most heat transfer surface for the space, making it ideal for heating and cooling applications with high heating loads (high drying capacities). The residence time – the amount of time that the treated material spends in the machine – can be adjusted from minutes to hours. The machine’s operator can achieve some back-mixing immediately upon feeding, enabling materials to be fed more gradually into the process. This is beneficial for high-moisture materials that might otherwise stick and deposit on the dryer surfaces. These dryers typically require a larger capital investment when compared with other dryers, but this cost is usually offset by the large capacity.
Mixers (Figure 4) can be employed with a hollow wall for heating and cooling in either a standard U-shape or a cylindrical body. Several rotor configurations, such as paddles or ribbons rotating on a horizontal shaft, provide mixing and flow of the material, but typically do not provide heat transfer.

Mixers are most commonly employed for batch operations that require residence times in excess of one to two hours. Heat transfer is limited to the walls of the vessel, and will typically not provide a lot of treatment.

Materials that require lower levels of heating or cooling, or heat-sensitive materials that must be carefully managed to avoid product degradation or damage, are best processed using this technology. The rotor configuration of a mixer can consist of paddles, arms, or, more commonly, a series of metal ribbons, making them easier to fabricate than the previously mentioned rotors. As a result, these mixers are among the least expensive of indirect thermal technologies. Generally speaking, mixers are best for specialty materials that undergo chemical reactions or require long cycle times.

Figure 4: The Continuator Dryer offers a jacketed vessel that uses indirect heat transfer. Several rotor configurations are possible depending on the material design requirements. Vessels are designed for batch or continuous operation and to meet pressure or vacuum parameters. By adding gas through purpose-built nozzles in the bottom of the vessel, the dryer maximizes gas contact with the product. This process enhances mass transfer of volatile materials, making the Continuator ideal for removing tightly entrapped volatiles in materials with very fine particle size or poor flowability.
## Types of Heat Transfer Media

The most common types of heat transfer media are listed in this table. The primary selection method for fluid is temperature. When more than one fluid can be used, the maximum material temperature is then considered to prevent final product damage.

<table>
<thead>
<tr>
<th>Temperature Range (degC)</th>
<th>Heating Source</th>
<th>Advantages</th>
<th>Disadvantages</th>
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| Water/Glycol 0-100        | Chiller        | • Low utility requirements  
                        | Electric Heater  
                        | • Low cost  
                        | Natural Source  
                        | • Limited temperature capabilities  
                        | • Corrosion protection may be required  
                        | • Water treatment post-process may be required for single-pass systems |
| Saturated Steam 105-180   | Natural Gas or Electric Boiler  
                        | • Use existing boiler capacity = lower capital cost  
                        | • Quick heat-up and cool-down  
                        | • Little fluid in the flow spaces after shut-down  
                        | Requires a boiler engineering for most plants  
                        | • Additional safety provisions required  
                        | • Increased equipment costs for higher pressure construction |
| Hot Oil up to 375        | Natural Gas Burner  
                        | • High temperature inputs  
                        | Electric Immersion  
                        | • Recirculating system improves efficiency  
                        | • Easy to find commercially  
                        | • Oil will degrade over time and require replacement  
                        | • Slow heat-up and cool-down  
                        | • Clean-up is difficult (if draining is required)  
                        | • Usually requires dedicated heating system |
| Molten Salt 150-500      | Natural Gas Burner  
                        | • Provides maximum temperature input  
                        | Electric Immersion  
                        | • Safety due to extremely high temperatures  
                        | • Can require special MOC (high nickel alloys, high temp seals, etc.)  
                        | • Not suitable for heated shafts  
                        | • Anti-freezing provisions required on all process lines  
                        | • High operation and maintenance costs |
In Conclusion

Most materials can be successfully treated using one or more of the options presented above. Your unique process, plant and capital requirements will steer you toward the technology that best fits your company’s goals.

If you have narrowed your technology choices down to a few viable options, your next step should be to find a manufacturer that can provide sample evaluations, for little or no up-front cost, to enable you to gauge process feasibility and narrow down your technology options. You will want an equipment manufacturer that has pilot-scale equipment capable of simulated product runs which can then be used to design and guarantee commercial production.

Don’t be surprised if a single-line manufacturer with only one or two technologies tries to make its technology fit your process, rather than optimizing your process using the most efficient, cost-effective technology. If you find that more than one technology type could fit your needs, it pays to explore each of them to find the best solution.

It may be best to find a single equipment manufacturer with deep experience and a broad product line that covers several of the referenced indirect thermal processing technology options. Otherwise, you will need to repeat your evaluation process with multiple companies. This will help you select the right solution for your needs, rather than basing your decision on the equipment manufacturer’s selection of equipment.

About Bepex International

Bepex International serves the global food, chemical, polymer and renewable markets by providing custom process system development services, including custom-designed industrial scale process systems, equipment and programs. With an 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.