Indirect vs. Direct: The Heat Transfer Method Does Affect the Process

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Can your product withstand exposure to the heat source? Drying efficiency and finished-product quality are influenced by the heat transfer mode employed in your dryer.

For almost every drying process -- and for many other processes -- it is necessary to transfer energy, via heat from a source, to the process. The energy heats up, or increases, the temperature of the raw or feed material.

To achieve this, the energy must be transferred from the heat source to the material to be heated via a carrier. In drying applications, the primary carriers usually are gaseous or solid, but in some applications, the carrier takes the form of waves -- microwaves, radiation or other radio frequency (RF) technologies. Liquid carriers typically are used as an intermediate or secondary carrier in the drying process.

In general, carriers and the modes of heat transfer are grouped into two sets: direct or indirect. The distinguishing characteristics of each mode make it more or less suited to a particular application. To understand which applications each mode is suited for, you must understand what "direct" and "indirect" really mean and what effect each mode has on the process.

Almost every source of energy -- and certainly every viable commercial method of generating energy -- requires that at least one substance experience a significant increase in temperature, via reaction or transfer. Almost all industrially usable sources (with the possible exception of nuclear) require the combustion of a fossil fuel source. For most applications, energy generation is local to the plant. The one notable exception is the use of electricity, where generation occurs at the power station.

Direct and Indirect Heat Transfer

For applications where combustion of a fuel generates the heat source locally, the distinction I prefer to use to differentiate between direct and indirect transfer is to establish whether the products of combustion come into contact with the material being processed. If they do, the system is direct. If they do not, obviously, the system is indirect. With noncombusting heat sources, this distinction is somewhat more complicated, raising the question of how direct is "direct" and how indirect is "indirect." Furthermore, does it matter? Purists would argue, but in this article, the application is defined by the answer to this fundamental question: Is the final carrier, which makes contact with the product, in direct contact with the primary heat source?

Using this definition, you can see that trying to define a dryer type or configuration as direct or indirect is futile. There are no absolutes, and while some equipment is exclusively one or the other -- for example, a drum dryer is always indirect; microwave always is direct -- most dryers can operate effectively in either mode. Therefore, the definition of direct vs. indirect relates more to the heat source than the drying technology employed.

Comparing Heat Sources

Fossil fuels constitute the majority of commercially available energy sources used to generate heat. The supply of these fuels is diminishing, however, without a viable alternative having yet been fully developed or accepted.

Most fuels contain carbon and hydrogen; therefore, they are collectively termed hydrocarbons. Grouped by form into solid, liquid and gaseous fuels, each form has its own unique idiosyncrasies and peculiarities.

Generally, the cost of using a given fuel is dictated by logistics. Solid fuels must be stored, and the investment for ash and other required materials-handling and pollution-control systems can be high. Liquid fuels also must be stored and pumped, and in some applications, require heating before they can be used. Pollution control requirements typically are less with lighter and cleaner fuels. Also, gaseous and liquid fuel efficiencies are higher than solid fuels because the excess air requirements to ensure complete combustion are less. (Therefore, there are smaller losses.)

Solid Fuels. Where coal is a freely available, it is a relatively inexpensive energy source. Obtainable in many grades and sizes, its quality and calorific value as well as the consistency of the particle size distribution largely determine its cost. As a rule, finer and more consistently sized coal is more expensive. Beyond the normal products of combustion, some coals may have a particularly high sulfur level, which can lead to equipment corrosion problems if high enough concentrations of acid are allowed to form. Logistics and distribution may contribute additional costs to using this fuel.

Coal commonly is combusted using pulverized fuel burners, fluidized bed combustors or stokers such as a chain grate underfeed stoker. Particle size and capital investment restrictions are the major influencing factors in the selection process.

As with most combustion processes, the temperature of the gases generated during the combustion of coal is high. Introducing these gases, diluted by makeup air, directly into the process would affect a direct-drying system. Operating as an indirect system, the gas gives up its heat to water (steam), thermal oils or gases (nitrogen, air or other gases). In these cases, the primary heat source is coal, and the secondary source is steam, oil or gas. Depending on the dryer type, the steam or oil may need to pass through another heat exchanger to heat another carrier -- air, for example -- for an air-drying system.

Other possible solid fuel sources include process byproducts and waste materials, which can provide an economic advantage to the process.

Liquid and Gaseous Fuels. Petrochemicals and their derivatives, including natural gas, form the second fuel group. Liquid systems mainly utilize atomizing burner systems while gaseous burners most often incorporate a mixing or turbulent action to improve combustion. Whether burning a liquid or gaseous fuel, the burner requires a combustion chamber -- often integral to the dryer, as is the case with certain rotary cascade and fluid bed dryer designs -- and a supply of combustion (primary) and excess (secondary) air. As with coal, cleaner, more efficient combustion, which produces minimal losses, occurs near stoichiometric conditions (perfect combustion). Different fuel oils and gases produce different combustion emissions, which can be commercially optimized for the process.

In general, as fuel viscosity increases, cost falls. Correspondingly, as viscosity increases, fuel quality degrades as the combustible product becomes dirtier and more contaminated. As a consequence of the higher viscosity, many of the heavy fuel oils (and some light fuel oils) require an additional heating system to reduce fluid viscosity and enable the oil to flow and be atomized.

Liquid and gaseous fuels are used extensively as direct and indirect heat sources. In direct systems, the combustion and excess air specifications are designed to meet the necessary air requirements of the drying process. With clean-burning gases, the heat source can be used directly on sensitive products without the products of combustion degrading product quality due to contamination. Liquid and gaseous fuels also can be used with a secondary heat source, similar in design to solid-fuel indirect heating systems.

Electricity. Not a fossil fuel but rather a product thereof, electrical heat generation deserves a section of its own. Although electricity often is the most costly energy source per unit output (BTUs or joules), a holistic investigation of the process may present a more favorable outlook. Electrically powered heat-generating equipment frequently offers unmatched versatility.

The range of electrically powered heat-generating equipment available is vast. It includes implicitly direct heat sources such as microwave, infrared, radio frequency and dielectric technology as well as conventional indirect elements such as silicon carbide, In-coloy, and Inconel heaters. A relatively clean fuel, electricity also is effective for indirect applications such as boilers and oil heaters.

Steam. In the same fashion as electricity, steam frequently is referred to as a heat source. Although steam geysers have been successfully harnessed to generate power, it is not common to use naturally occurring steam in industrial applications. Instead, steam typically is generated using combustion or electricity to heat, vaporize and pressurize water.

Most applications employ steam as an indirect source, using either a heat exchanger to transfer heat to a gas carrier or a jacketed vessel or drum to heat a surface. It also is used as a direct heat source to achieve effective drying.

The amount of energy that can be carried by steam is related to the pressure at which the steam is delivered. The higher the pressure, the greater the energy contained. Obviously, as the pressure increases, the steam-generating equipment and associated piping reticulation must be more rugged and robust. This can increase the capital investment significantly.

Understanding the Application

Obviously, to properly select the optimal drying system, one must first specify the process requirements. Once the process mandates and operating conditions have been examined rigorously, you will be able to determine whether a direct or indirect system is best suited to your utilization.

Evaluating several key factors can help you determine whether the mode of heat transfer should be direct or indirect. Consider the:

- Effect of the products of combustion on the final product or the environment (external as well as the fabric of the equipment).
- Effect of contaminants on process steps following the drying stage.
- Stability (oxidization, reaction, etc.) of the feed and product.
- Toxicity, volatility and explosiveness of the material.
- Material's sensitivity to common carriers and temperature.
- Material form (liquid, slurry, granule, solid, etc.).
- Suitability of the technology to the process.
- Total number of plant-wide users and availability of a common heat source.
- Availability of fuel.
- State and federal environmental regulations.
- Quality requirements affecting the intended product market. For example, is the product

for human consumption?

After thoroughly evaluating each of these concerns, one can select the optimal drying technology. The default selection typically will be direct heating, but this decision will depend on the technology proposed. For example, air-drying systems most commonly are direct, with the carrier heated by some combustion process. This same air can be heated indirectly using a heat exchanger containing steam, hot air or hot oil. Only if the process dictates the need -- or if an indirect heat source is economically available -- would an indirect system be employed in these circumstances.

In other applications, the most appropriate unit would be an indirect dryer -- even if the product does not warrant it from a quality point of view. For example, some robust slurries are best suited to be dried in a hollow-flight paddle dryer, an implicitly indirect system.

There are advantages and disadvantage to using either drying mode: heat transfer efficiency, equipment cost, the level of process complexity and fuel availability. So, in most cases, the technology used should be selected primarily based on the process.