Curing and Drying Operations: The Pros and Cons of Infrared Heating

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Low thermal efficiencies are common in many types of process heating equipment, making process heating a prime candidate for energy-saving improvements. In this pamphlet, we focus on opportunities within drying and curing operations to improve energy use, product quality, and overall productivity. In many cases, infrared heating or hybrid systems that combine infrared and convection technology offer several advantages over convection heating alone.

Curing and Drying with Infrared

Infrared (IR) radiation is commonly used to dry textiles and paper products, heat metals and plastics, and dry and cure paints. For drying and curing operations, infrared heating offers several potential advantages over convection heating.

IR Versus Convection Heating

Medium-wavelength electric IR heating is especially well-suited to the curing and drying of coatings, because these wavelengths correspond well with the absorption bands for water, which most coatings contain. Additionally, since IR heating does not penetrate the surface very deeply and generally only heats the outer surface, it is applicable for drying coated and printed products.

But perhaps the greatest advantage of IR heating over convection heating is that IR emitters can deliver heat in exact amounts directly to a specific point. IR radiation is a line-of-sight technology, meaning that it only delivers heat to the surface of an object that is in a direct line of sight from an IR emitter. Depending on the product, this can be either an advantage or a disadvantage: Flat parts absorb energy best; complex curved parts require either more IR emitters or supplemental convection-heating technology. Additionally, because IR heating only heats the surface of the material, it leads to significant energy savings when drying and curing paints and coatings: no heat is wasted on the underlying materials.

Table 1 summarizes the comparison between IR and convection heating. The curing of powder coatings is one of the best applications of IR heating, achieving good quality finishes with excellent energy efficiency. Where complex shapes are an issue, hybrid systems can be used (see "Hybrid Drying System at Progressive Powder Coating" case study below). Powder coatings offer many advantages over traditional liquid coatings, including notable materials-cost savings and significantly reduced emissions of volatile organic compounds from the curing process. The quality of the finishes and the range of applications for powder coating have continued to improve in recent years.

Gas Versus Electric IR Heating

IR radiation is generated using one of three different technologies: electric, gas catalytic, or radiant gas (and radiant gas systems are mainly used for space heating rather than process heating). Electric and gas-catalytic IR technologies

Table 1: Comparison of heating technologies for curing and drying

Infrared heating offers several potential advantages over convection heating for curing and drying operations. Electric infrared technology offers more flexibility than gas-catalytic in terms of the desired heating intensity.

Advantages/features	Convection oven	IR technology: Gas	IR technology: Electric
Distributes heat evenly, even for products with complex shapes	●		
Not sensitive to reflective properties of coatings	●		
Lower-cost energy source (when compared in dollars per unit of energy consumed)	●	●	
Uses less energy when only surface heating is required		●	●
Provides well-controlled, low-intensity heat		●	●
Provides highest-intensity heat			●
Intensity can be easily adjusted for different products			●

Note: IR = infrared.

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have specific characteristics that make them more or less appropriate depending on the material and the type of process. Gas-catalytic IR systems generally require a greater capital investment than the other two, but they have lower operating costs.

To decide which technology is right for a specific product or process, a number of parameters must be considered, including product quality, operating costs, and production rates. In processes that require fabric and paper drying, gas-catalytic technology has a slightly superior heating efficiency because of the intensity of the radiation it emits and the amount of time the product spends in the oven. In general, a gas-catalytic IR system is a good choice for materials that require a lot of energy, such as some textiles, because its fuel costs are lower than those of electric IR (on a $/Btu basis). Electric IR is better suited to sensitive materials that require a less-intense heat or to processes that need quick response times or shorter bursts of intense radiation from the heating equipment.

Gas-catalytic IR technology has a fixed power density that depends on the temperature of the fuel-oxygen reaction; it generally does not exceed 2 kilowatts per square foot (kW/ft^2—that's 22 kilowatts per square meter [kW/m^2]). In contrast, electric IR ovens can quickly and easily vary the intensity of emitted heat while achieving power densities of up to 37 kW/ft^2 (400 kW/m^2)—a characteristic that makes them superior for rapidly heating metals.

That's PHAST!

For drying and curing operations, in addition to considering alternative technologies such as infrared heating, there are several opportunities for improving the efficiency of existing operations, including adding insulation, optimizing burner performance, improving controls, and adding heat recovery. The U.S. Department of Energy's Industrial Technologies Program has developed software called the Process Heating Assessment and Survey Tool (PHAST) that can help energy managers identify energy-efficiency opportunities. PHAST can perform three primary tasks: survey all process heating equipment and create a detailed energy-use report, analyze the energy balance of a specific piece of equipment and make recommendations for improvements, and calculate the benefits of specific energy-efficiency upgrades.

PHAST has been tested in large industrial applications with great success. For 13 large facilities in the aluminum, steel, mining, and petroleum industries, PHAST was able to identify process heating improvements resulting in average energy savings of over US$1 million per year per facility. This program is available free from the Industrial Technologies Program web site (www.oit.doe.gov/bestpractices/software_tools.shtml#phast). Specialized training and certification courses are also available.

Convection Ovens

For process heating operations in general, the most common technology is the convection oven, which heats and circulates the enclosed air within the oven, transferring heat to the part primarily by the movement of the heat-transfer fluid (in this case, air). This technology is very effective in many applications, such as annealing or heat-treating, where the entire part needs to be heated to and maintained at a specific temperature.

For drying and curing operations, convection ovens are best suited to products with complex shapes. Because convection ovens transfer heat via air, any surface that is exposed to the air will absorb the heat evenly, which leads to uniform heating. This is not possible with line-of-sight heating technologies like IR. And, in a convection oven, the existing color or surface coating has no effect on the ability of a part to absorb heat, but in IR devices, effective heat transfer can be inhibited by coatings with reflective properties.

Convection ovens are also relatively easy to control once they are running and programmed, as long as the products do not have significant variations in size or density that would require different temperatures or lengths of time in the oven. However, painting and—in some cases—curing applications generally only require that heat is transferred to the surface of the part to achieve the desired results. For these applications, IR or hybrid heating systems are often a better choice.

Case Study: Hybrid Drying System at Progressive Powder Coating

Many manufacturing facilities have multiple product lines that use the same drying equipment. Progressive Powder Coating, located in Mentor, Ohio, had to slow down the conveyor running through its 120-foot (37-meter) convection oven to properly cure the coatings on thicker metal products. This slowdown required corresponding adjustments to the intensity and duration of the applied heat, resulting in costly production delays and bottlenecks. With the help of Dominion Power consultants and the PHAST software package, Progressive decided to add a 40-foot (12-meter) gas-catalytic infrared oven to preheat and cure the powder coatings before they entered the convection oven. The new oven uses a flameless technology to produce low-temperature, uniform heat. The upgrade has yielded impressive results for Progressive Powder: a 50 percent increase in production rates and US$54,000 in annual energy savings—achieving a 2.5-year simple payback.

Case Study: Vocational Education Center Upgrades to Electric Infrared System

The Norfolk Technical Vocational Center in Norfolk, Virginia, recently chose to install an electric infrared drying and curing booth in the auto-body painting department, replacing a gas-fired convection oven. The gas oven required four to five hours to completely dry a car; the IR system can complete the job in less than two hours. The painting instructor, Jerry Wellings, is also very pleased with the maintenance level of the new oven. After two years, he has yet to change the air-intake filters, whereas the gas-fired system required multiple filter replacements every year.

Electric infrared technology also provides the shop with significant versatility in finishes. Switching from one paint formula or method of application to another is also much simpler with the new drying system. The infrared heaters can be easily adjusted for waterborne painting one day and for a powder-coated finish the next.

Hybrid Convection/IR Systems

Hybrid systems utilize both fuel-fired convection ovens and IR heating to create the most effective system for many processes. Many drying applications are particularly well-suited for hybrid systems because of what is known as the "boundary effect": When water-based coatings are dried, a layer of moist, saturated air forms near the surface of the product. This air layer tends to hinder the drying process. In one configuration of a hybrid system, the movement of air in the convection oven in the initial drying stage helps to force this moist air layer away from the product, allowing the IR heaters to finish drying the part in a second drying stage. This combination of convection and IR technologies works well for drying inks, coatings, finishes, or adhesives applied to sensitive materials—such as film, release paper, or some types of fabric—where the more controlled IR drying in the last stage helps to avoid damage to the material from excessive heat.

Another widely used application of hybrid technology is an IR preheat stage in series with a convection oven. Since IR technology has a very small footprint, it is easy to add a small oven to the beginning of a process line. This preheating stage allows the coating to begin curing as soon as it enters the convection oven. Without the IR zone, the part would need much more time in the convection oven. This practice allows parts with hidden areas to dry and cure evenly in the convection stage, while the infrared stage helps to increase the production line speed and production rate. If there is no additional floor space, the IR heaters can even be added to the inside of the convection oven in the first several feet of the line.

Additional Resources

If you need assistance in evaluating the best technology for your processes, you can start with your utility or energy service provider. Consultants or vendors of the process heating equipment can also provide the needed expertise. For more information, you can also check out these resources:

- Powder Coating Institute, "Benefits of Powder Coating," available at http://cage.rti.org/linksFrames.cfm?myU=http://www.powdercoating.org.
- U.S. Department of Energy, Industrial Technologies Program, "Seven Ways to Optimize Your Process Heat System," available for download at www.oit.doe.gov/bestpractices/process_heat/pdfs/em_proheat_seven.pdf.
- U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Improving Process Heating System Performance: A Sourcebook for Industry" (September 2004), available for download at www.oit.doe.gov/bestpractices/pdfs/proc_heat_sourcebook.pdf.
- Natural Resources Canada, Office of Energy Efficiency, "Process Furnaces, Dryers, and Kilns" (1987), available for download at http://oee.nrcan.gc.ca/ici/english/password/pdf/EMS_07_process,furnaces,dryers.pdf.