Taking the Mystery Out of Infrared Heating

Interested in infrared and curious about how to use it? These 10 tips can help you answer your questions about radiant heating and whether it is right for your process.

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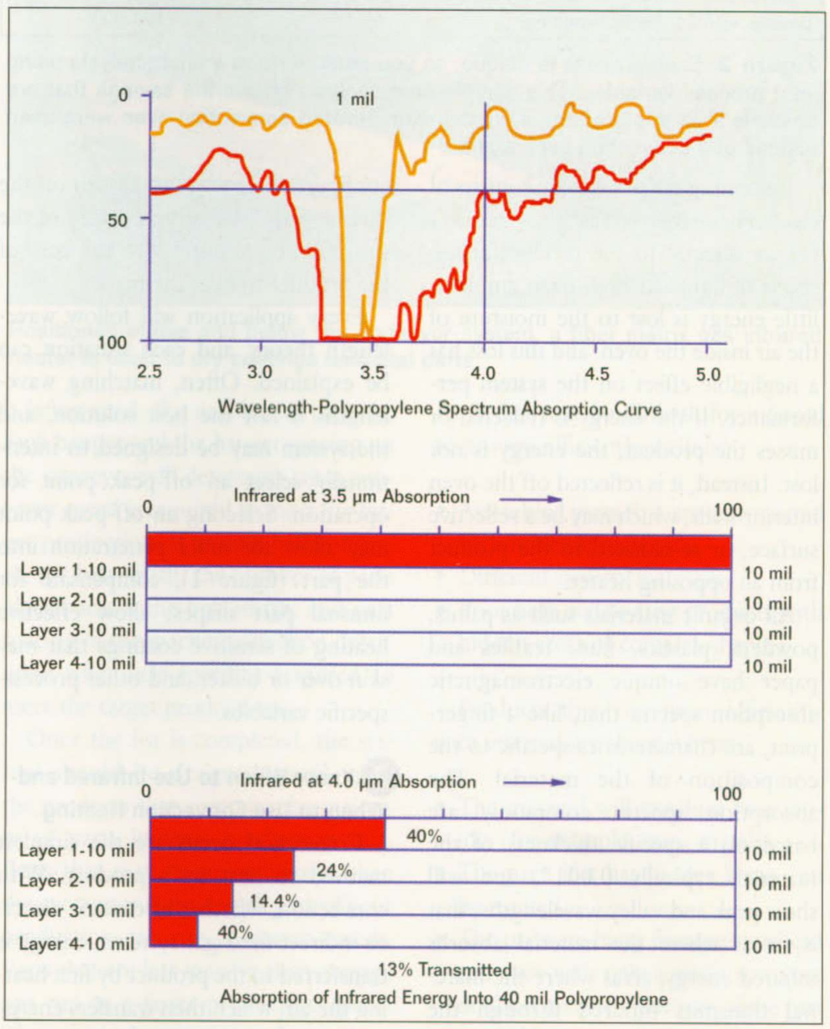
Infrared heat processing systems have been available for several decades. Due to current competitive pressures from the Far East and rising energy costs, many applications now are being considered for use with infrared that may not have been considered previously. The following 10 tips are common points that should be taken into account by companies contemplating the use of infrared within their manufacturing facility.

1 Understand How Infrared Works

Infrared systems contain infrared heaters, or emitters, set at higher temperatures than the part will attain. The final part temperature is determined by the dwell time of the part in the infrared oven. Radiant energy transfer is increased as the difference between the heater temperature and the part temperature increases.



All organic materials such as paints, powders, plastics, film, textiles and paper have unique electromagnetic absorption spectra that, like a fingerprint, are characteristics specific to the composition of the material.

COST ANALYSIS	Convection Oven	Combination Infrared/ Convection Oven
Process	Powder Coat Metal Parts	Powder Coat Metal Parts
Conveyor Type	Overhead	Overhead
Line Speed	10 ft/min	10 ft/min
Product Weight	50 lb/ft	50 lb/ft
Desired Cure Cycle	Raise to 350°F & Hold for 10 minutes	Raise to 350°F & Hold for 10 minutes
Oven Length	100'	110'
Infrared Length	0	10'
Energy Consumption		
Convection	4 MBTU/hr	0.8 MBTU/hr
Gas Infrared	0	1.7 MBTU/hr
Total	4 MBTU/hr	2.5 MBTU/hr
Time to Temperature	7 min	1 min
Time at Temperature	3 min	10 min
Cost per MBTU Gas	$7	$7
Operating Cost/hr	$28	$17
Cost/2000 Shift Year	$56,000	$35,000
Savings with Infrared/Convection	0	$21,000

Figure 2. Each process is unique, so you must perform a cost analysis using your process variables. This sample cost analysis shows the savings that are possible if, in this process, a combination infrared/convection oven were used instead of a convection oven alone.

Infrared or radiant energy consists of electromagnetic waves that transfer energy directly to the product at the speed of light. At high oven ambient, little energy is lost to the moisture of the air inside the oven, and this loss has a negligible effect on the system performance. If the energy is reflected or misses the product, the energy is not lost. Instead, it is reflected off the oven interior walls, which may be a reflective surface, or re-radiated to the product from an opposing heater.

All organic materials such as paints, powders, plastics, film, textiles and paper have unique electromagnetic absorption spectra that, like a fingerprint, are characteristics specific to the composition of the material. The absorption spectra commonly are based on a specific thickness of the material, typically 0.001", and will show peak and valley wavelengths; that is, areas where the material absorbs infrared energy, areas where the material transmits infrared through the material, and areas with partial absorption. With this knowledge, a heater or emitter wavelength can be selected to configure the energy to absorb on the surface with little or no heating of the substrate, or transmit into the core of the product to heat the mass.

Every application will follow wavelength theory, and each situation can be explained. Often, matching wavelengths is not the best solution, and the system may be designed to intentionally select an off-peak point for operation. Selecting an off-peak point may allow for more penetration into the part (figure 1), compensate for unusual part shapes, allow effective heating of sensitive coatings that may skin over or blister, and other process-specific variables.

2 Know When to Use Infrared and When to Use Convection Heating

Convection ovens are the simplest method to heat up a product. With convection, whether electric or direct- or indirect-fired gas systems, energy is transferred to the product by first heating the air, which then transfers energy to the product.

Electric systems commonly use open coils, metal-sheath heaters or fin-type heaters to heat the air. Direct-fired gas systems use a combustion flame to heat the air directly, and the products of combustion become part of the process air. Indirect-fired gas systems use a heat exchanger to separate the process air from the combustion air, which reduces transfer efficiency but protects the product from the combustion products. A circulating fan will help promote air temperature uniformity within the oven chamber as well as increase convective heat transfer into the product.

To understand the difference between convection heating and infrared (radiant) heating, consider the following example: You are sitting in front of a closed window before sunrise, and the room is cool. You turn on the heat in the room, which slowly raises the temperature of the room to your comfort level. When the sun starts to radiate through the window, you immediately start to feel warm although the air temperature in the room has not changed. The sun is providing infrared energy to you faster than the air in the room is conducting it away. Infrared energy can be transferred directly to a product at a much higher rate than convection.

In a convection oven, the product spends a significant portion of the total dwell time in the oven just reaching the process temperature. This is the major energy consumption portion of the process. Infrared will raise the product to a temperature more rapidly than the convection oven due to the higher energy transfer rate and will heat the product at a higher efficiency. A convection oven with a typical 20 to 30 min dwell time may take 15 to 20 min to bring the parts to temperature; an infrared oven may reduce the time to 1 to 3 min. This is due the fact that infrared is a direct form of energy transfer that does not rely upon conduction through a medium such as air. Other benefits include reduced conveyor length, reduced fixturing and savings in floor space. The overall goal is to reduce per unit processing costs.

3 Choose Energy Source Wisely

When selecting between an electric and a gas infrared system, consider:

- Operating cost.
- Controllability of the process.
- Repeatability.
- Heat up and cool down response times.
- Byproducts from the process.
- Initial capital cost.
- Floor space required by the system.
- Maintenance requirements.
- Installation costs.

These variables must be reviewed for each product or project as they will change from plant to plant and from location to location.

A common first impression is that the energy cost for gas is less than the energy cost for electric; therefore, a gas system is the way to go. Under current market conditions, unless you have entered into a long-term contract with your natural gas supplier, gas pricing may be more volatile than electric costs. In many areas within the last two years, electric rates may have risen 5 to 10 percent while gas prices have exceeded 50 percent increases.

Gas infrared systems include catalytic and direct-fired designs. With the catalytic type, the gas is not burned but goes through a reaction with a catalyst to release energy that can be absorbed by the product. Byproducts of this process are carbon dioxide and water. Other types of gas infrared heaters burn the gas and have varied levels of emissions of nitrous oxide and carbon monoxide that are generated by the combustion process. The allowable emission levels for your facility may dictate whether a gas system is appropriate and whether pollution control equipment is required. Remember to include the emissions from the product such as evaporated solvent, release of agents used to manufacture the product, and byproducts of the curing process when calculating the emission level.

An electric system has no byproducts of combustion, but again, remember to include any emissions from the product when calculating the emission level. With an electric infrared system, generally higher energy transfer efficiencies can be achieved that may compensate for the difference in energy costs.

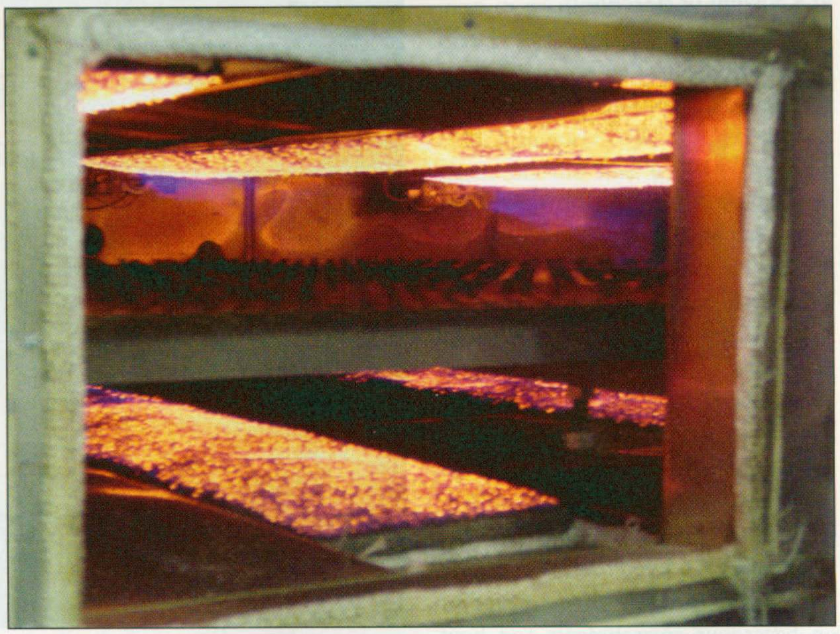
4 Define Production Goals Effectively

A production line, particularly within the finishing industry, must be flexible to handle many different part configurations, weights, shapes and base materials. To determine line speed and mass throughput, a list should be prepared with the scope of different parts that will be processed, the target production quantities, the characteristics of the parts and how the parts will fill the conveyor. If an overhead conveyor is being used, the number of parts on each hanger and the hanger spacing on the conveyor will determine what conveyor speed is required to meet the target production. If using a belt conveyor, the belt width, the number of parts placed across the belt width, and part spacing in the machine direction determine what belt speed is required to meet the target production.

Once the list is completed, the system should be designed based upon the products that compose the majority of parts in your production mix. Parts that may be more massive than the average and are a small part of your production can run at slower speeds. Parts that are less massive than average can run at a faster production speed. The nominal system speed — where the majority of the parts meet their production goals when the range of parts that will run faster or slower is taken into consideration — should be the basis for the system design. Designing to meet the requirements for the heaviest part or a part that is run infrequently may cause the system to be overdesigned.

5 Check Compatibility Of Parts with Infrared

The goal is to determine if a system designed with infrared will provide advantages over a convection system.



Positioned above and below the conveyor system, a fiber matrix gas infrared heater is used to dry coatings on metal parts.

Parts that may be difficult for infrared to process efficiently include:

- Assembled parts that are constructed with multiple materials.
- Different density materials.
- Poor heat conducting products with hidden areas of complex shapes.

Products that run most efficiently with infrared are those where:

- The material will conduct heat rapidly (for example, most metals).
- The part, if it has hidden areas, can be rotated.
- The parts are hung from an overhead conveyor with only a single row (not doubled up where portions of the part are hidden from the infrared energy) or the parts are low profile designs, flat panels or continuous webs.

To compensate for parts that are not ideal candidates for infrared, combination infrared/convection systems often are designed. The higher the portion of the process energy that is provided by the convection, the lower the total oven efficiency will be. At some point, the benefit of a combination infrared/convection system will no longer be economical and a traditional convection system should be employed.

6 Understand How to Use Infrared in a Solvent or Hazardous Environment

Hazardous production conditions may require that the infrared heating system:

- Be located within a classified area that has potentially explosive solvent concentrations.
- Process material that generates potentially explosive concentrations of solvent.
- Process material that has a critical temperature at which it becomes hazardous, explosive, combustible or otherwise.

The National Fire Protection Agency (NFPA) has extensive documentation on hazardous environments and how to safely install process equipment.

Generally, a solvent-based system is designed with sufficient dilution air and exhaust so as to maintain a 4:1 safety factor (25 percent lower explosive limit, or LEL) over an explosive mixture. The oven may be designed with air purging of wire-ways and other enclosed areas, intrinsically safe electrical devices, monitoring of the blowers to ensure proper airflow/volumes, and solvent-monitoring equipment. The design should ensure that there are no areas within the system that can trap or collect a solvent mixture. The type of solvent — for example, whether it is heavier or lighter than air, its flashpoint, and other solvent-specific characteristics — will influence the system design. In extreme cases, the infrared heaters can be in a separate chamber that is continuously purged with positive-pressure clean air, and the heaters can radiate through a transparent quartz window to the product. Gas catalytic infrared heaters produce their energy through a catalytic reaction and not through combustion, and many are approved for use directly within a hazardous environment with explosion-proof electrical connections.

Areas of caution are when the process temperature approaches the temperature where the product becomes hazardous. One example of this is a product that must be dried and cured at a temperature that is close to the temperature at which it will spontaneously combust.

7 Realize the Differences Between Short, Medium and Long Wavelength Infrared

Infrared heaters are available that emit in the short, medium and long wavelength regions of the infrared spectrum. The most efficient type of heater for a particular process is determined by the actual process and product demands. This relates back to the electromagnetic absorption spectra of the product being heated and how much energy transmission is required by the process.

Short-wavelength, or high intensity, heaters emit energy in the wavelength region shorter than 2 µm and are available with energy outputs up to 200 W/in^2. Because short-wavelength heaters may emit some of their energy within the visible light region, the process may be sensitive to different color coatings run and may require different oven setups for each. Short-wavelength energy has the tendency to penetrate through thin organic coatings. Near infrared (NIR) heaters, a relatively new technology, fall within this category. Short-wavelength heaters generally are quartz-tungsten lamps or bulbs and usually utilize reflectors or refractory to direct some of the energy produced to the product. Anticipated heater life is approximately 5,000 hr when operating at rated power.

Infrared is used to preheat a heavy metal mold, maintaining close temperature tolerance through the mold mass.

Medium-wavelength, or medium intensity, heaters emit in the wavelength region between 2 and 4 µm with output energy levels between 15 and 60 W/in^2. Medium-wavelength heaters are available in many configurations including lamps, tubular quartz, flat panel heaters, ceramic, bulbs, metal-sheath heaters and more. Medium-wavelength infrared has the tendency to be absorbed by organic coatings directly. The peak absorption of water falls within this regime, making it suitable for efficiently heating moisture-rich products or water-based coatings. Some heater designs have built-in reflective devices to reduce maintenance. Life expectancy can exceed 30,000 hr.

Long-wavelength, or low intensity, heaters emit in the region greater than 4 µm with energy levels generally below the 15 W/in^2 level. At the lowest energy levels, long-wavelength heaters approach the lower efficiencies of a convection oven.

8 Design the Conveying System to Be Infrared Friendly

Infrared, like light, will transfer energy to what it can see. Within an infrared oven, energy that is not directly absorbed by the product will be reflected or re-radiated (typically at a lower wavelength) within the oven enclosure, providing many opportunities for the energy to be absorbed by the product. The material that the product is made from may assist in transferring energy that is received from the infrared heater to hidden areas on the product. This is particularity true with metal products that have a high rate of conductivity.

With an infrared system, the most efficient presentation of a part is in single file. If the coating is on one side, the infrared can be placed on the coated side or both sides to reduce overall dwell time in the oven. For three-dimensional parts, rotating the part through oven often will enhance the uniformity to which the product is heated.

Infrared does not achieve peak efficiency when parts are large, complex shapes; when they are conveyed with multiple parts across a conveyer width; or when they are hung from a rack where one part may be blocked or hidden from the infrared energy by another part. Unless you are relying upon conduction from the exposed areas or hot air assist, the product should have close to "line of sight" to the infrared energy.

9 Get Control — Open Or Closed Loop

Open-loop process control is where the infrared source, whether gas or electric, is set by a percentage of full power or capacity. This is similar to a basic electric or gas kitchen stove, where you have a low, medium or high setting. There is no information provided to the control system on the actual heater or product temperature.

An overhead conveyor carries powder coated parts from an electric infrared system.

Closed-loop process control utilizes a feedback device such as a thermocouple measuring the heater temperature or a noncontact device such as an optical pyrometer measuring the product temperature. Closed-loop control systems may automatically compensate for changes in ambient temperature, changes in product-entrance temperatures and fluctuations in line voltages on electric systems.

For noncritical applications where acceptable product temperature can be within a range of 25 to 50°F (14 to 28°C), open-loop control is more cost effective and may provide sufficient product control and process repeatability. Where tight temperature control is required such as less than 10°F (5°C), closed loop control is the preferred choice.

Combination systems can be employed where the first portion of the process is controlled open-loop to raise the product to a general temperature range and the final portion of the system is closed-loop, yielding the desired final temperature tolerance and repeatability for the total process.

Recipe-driven programmable logic controller (PLC) systems with touch-screen operator interfaces assist with automatic setup of the line based on the part being processed, saving time and reducing errors.

10 Consider Infrared for Retrofits and Replacement Systems

If your company has a convection oven or even an existing infrared oven that is not performing as needed to meet your production goals, consider a retrofit booster system. If the existing oven is in good condition and there is room on the line to add either an infrared preheat or post-heat system, a booster system may provide the greatest return on investment. A common application is an infrared preheat/gel system on a powder coating line. The infrared will provide energy to the part to melt and/or gel the powder. Actual per-part operating costs may drop because the energy consumed by the convection oven will be reduced to the energy required only to hold the part at temperature. Product quality may increase because with the booster system, the product may have a longer dwell time at temperature for better flow, reducing the orange peel effect and increasing desirable characteristics such as gloss and texture.

If your company plans to radically change the product currently running on the line or the existing equipment is old and inefficient, a new line may be a better choice. Performing a cost analysis such as the one in figure 2 will allow you to compare the economics of adding infrared to an existing system vs. replacement and showing the break-even points for each choice. **PH**

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