

POWDER CURING EQUIPMENT

How to save space and boost production with an infrared preheat-gel oven

Douglas M. Canfield

Casso-Solar Corp.

This article discusses how an infrared preheat-gel oven, often called a booster oven, enhances convection oven performance, boosts powder coating line speed, and saves floor space and energy. The article explains the operation of convection ovens as a prelude to understanding the purpose of an IR preheat-gel oven. Installation information also is presented.

In the past 4 years, the number of companies using powder coatings has increased by more than 13 percent, with projections of an additional 9 percent in the next 2 years. By the end of 1996, more than 36 percent of companies applying finishes will have powder coating capability¹.

To accommodate powder, many companies will have to upgrade or replace systems previously used for solvent-borne coatings. Some large finishing operations will find that the convection ovens they use to cure baking-type solvent-borne coatings won't run at the same production rates when curing powder coatings. As a result, they'll have to invest in additional curing capability and powder coating application systems. For the small shop that does mixed production of small lots of a variety of part shapes and sizes, the cost of such a change can be devastating.

To lessen changeover costs, the answer, in many cases, is an infrared preheat-gel, or booster, oven placed in front of the existing system (see figures 1, 2, and 3). An IR preheat-gel efficiently provides the additional energy for the process by rapidly raising the part and powder to the gel, or melt, temperature. The convection oven then completes the cure. Infrared preheat-gel ovens can also provide the following benefits:

- They can increase product quality by minimizing airflow on the powder during the gel stage, which lessens cross-color and dirt contamination.
- They can save floor space by decreasing the

required length of a convection oven or additional oven.

- They can save energy by more efficiently preheating the part with the capability to shut off unneeded vertical zones when running small parts.

Understanding convection heating

To increase your understanding of the benefits of an IR preheat-gel oven, you should first understand how convection ovens work. Convection ovens are the simplest curing system for organic coatings, such as powder coatings. Electric systems or direct- or indirect-fired gas systems transfer energy to the product by heating the air, which in turn heats the product. Electric systems commonly use metal-sheath heaters, open coils, or fin-type heaters to heat the air.

Direct-fired gas systems use a combustion flame to heat the air directly, which also allows the combustion byproducts to enter the process air. Indirect-fired gas systems use a heat exchanger to separate process air from combustion air. This two-step process is limited by the capability of the air to transfer the heat to the product.

To understand the difference between convection heating and radiant heating, consider the following example: You're sitting in front of a closed window before sunrise, and it's cool. You turn on the heat, which slowly raises the temperature of the room and your comfort level. When the sun starts to radiate through the window, you immediately feel warmer, although the temperature in the room hasn't changed. The sun is providing energy to you faster than the air in the room is conducting it away. This applies to finishing systems as well.

Radiant energy can transfer heat to the product at a much higher rate than convection. Up to 30 percent of the time in a convection oven may be used to raise

the part temperature and coating to the gel temperature of the powder. Infrared greatly shortens this time by rapidly and efficiently transferring energy to the part without the assistance of air.

When the powder is first applied, it's held on the part by an electrostatic charge or a preheated part that has started to melt the powder. Convection ovens rely on the velocity of the air to transfer the energy efficiently. The higher the air velocity, the more energy can be transferred to the part in a given space or time.

In the initial stages of a convection oven, air velocities must be kept very low so as not to blow the powder off the parts. This greatly reduces the efficiency of the oven and results in slow energy transfer to the product and long preheat-gel times. During this preheat stage, before gelling takes place, dirt particles either from the ambient intake air or from the combustion by-products in a direct-fired gas system can contaminate the powder coating. Whites, near-whites, and dark colors (such as black) are the most susceptible to this contamination. If mixed colors are run through the oven at the same time, dark-colored powder may blow off, contaminating light-colored parts and vice versa.

Understanding infrared heating

Unlike convection ovens, IR systems contain IR emitters, or heaters, set at higher temperatures than the

part will attain. The final part temperature is determined by the dwell time of the part in the IR oven.

Radiant-energy transfer efficiency is increased as the

FIGURE 2

An electric infrared preheat-gel oven for heavy castings

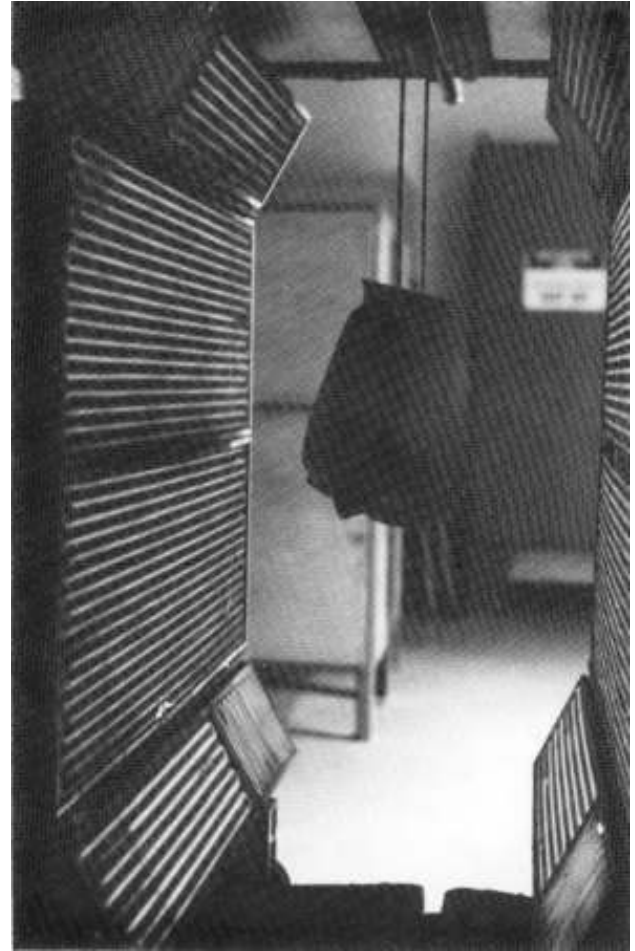


FIGURE 1

An electric infrared preheat-gel oven for metal pipe and tubing

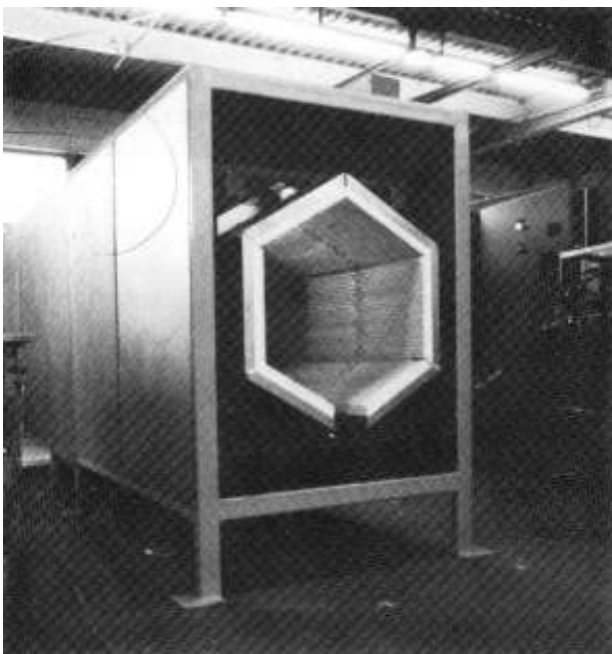
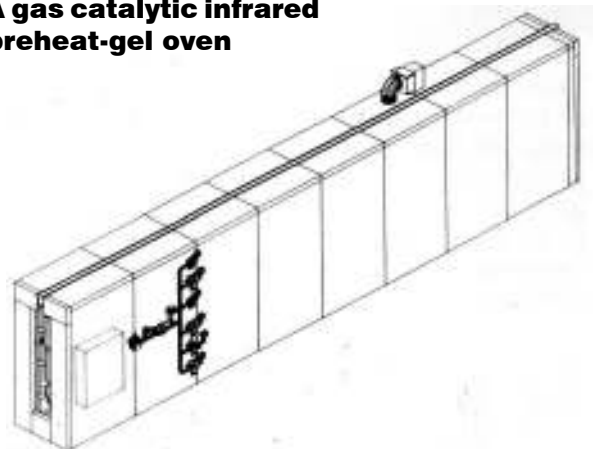


FIGURE 3

A gas catalytic infrared preheat-gel oven



difference between the heater temperature and the part temperature increases.

Because radiant energy is electromagnetic waves, it's transferred to the product at the speed of light. The air in the oven absorbs little of the radiant energy, and this loss has negligible effect on the system performance. If the energy is reflected or misses the product, the energy isn't lost. Instead, it's reflected off the oven interior walls or reradiated to the product from an opposing IR heater.

Absorption Spectra. All organic materials have electromagnetic absorption spectra, which, like fingerprints, are characteristic to the composition of the material. The absorption spectra will show peak wavelengths and valley wavelengths, areas where the coating easily absorbs the IR energy and areas where it's transparent to the IR energy.

Most organic coatings have absorption peaks between the wavelengths of 2.5 and 4.0 microns². (See Figure 4.) Infrared radiation, with output wavelengths corresponding to emitter temperatures, can be accurately measured, controlled, and applied to the product. When you set an IR heater to emit in a peak wavelength area, the energy is absorbed by the coating and the substrate is heated only by conduction. With IR energy applied at the valley wavelength areas (off-peak), the energy may pass through the coating to the substrate and provide the energy to flow, gel, and cure the coating from the inside of the coating out. The second method generally produces a higher substrate temperature for the part.

You must consider mixed batches, parts with multiple components made of different materials, such as a mix of steel and aluminum, and parts with multiple weight base materials, such as a heavy frame with light cross members. The IR oven system must be designed to safely gel the powder on all surfaces without overheating the powder on the lighter portions of the part or part mix.

This can be done with zones of IR alternating with unheated dwell zones. In some extreme conditions involving short batch runs with a large variety of mixed part weights, an IR system may not provide a time advantage over a convection oven but will still afford the benefits of a clean process environment.

Tunnel ovens may use the heater surfaces as the oven walls to contain the radiant energy in the most efficient manner. Radiant energy missing the coated product is contained within the oven by the radiant walls and is reradiated to the product, minimizing losses.

Infrared heaters are available that emit in long-, medium-, and short-wavelength regions. The most efficient type of heater for the process is determined by the actual product and process requirements.

- Long-wavelength, or low-intensity, IR heaters emit energy at peak wavelengths greater than 4.0 microns with energy levels generally below 15 watts per square inch.

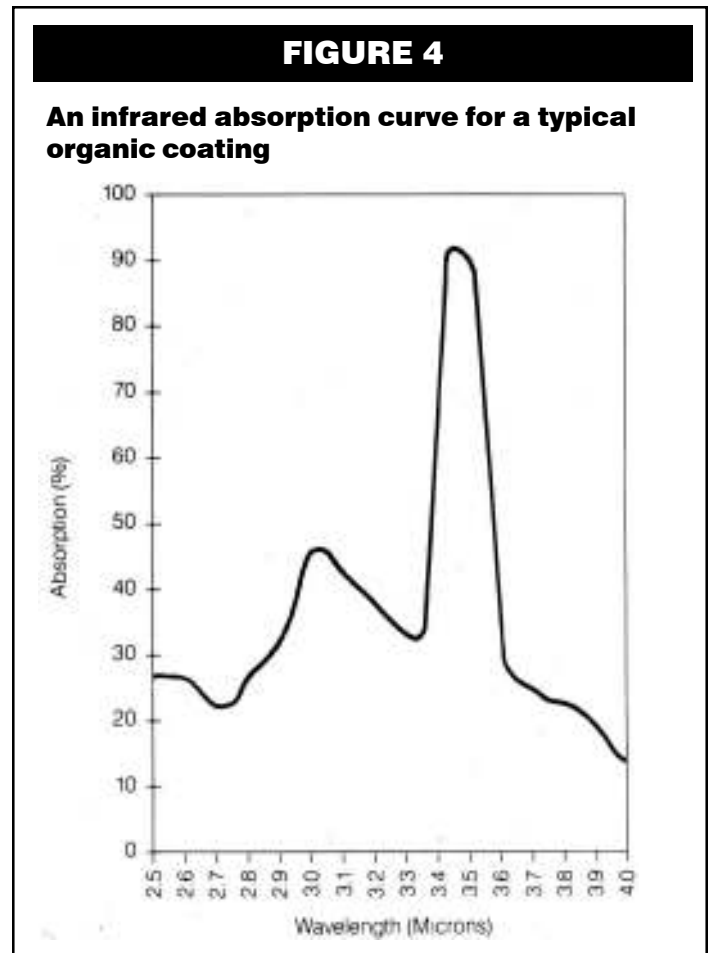
- Medium-wavelength, or medium-intensity, IR heaters emit at peak wavelengths between 2.5 and 4.0 microns with energy levels of 15 to 60 watts per square inch.

- Short-wavelength, or high-intensity, IR heaters emit energy shorter than 2.0 microns with energy levels up to 200 watts per square inch.

Heaters operating in the short-wavelength region that overlaps into the visible-light range may be color sensitive and require different oven setups for different colored powder coatings. The visible portion of the electromagnetic spectrum ranges in wavelength from 0.38 to 0.76 microns³. Sometimes the correct selection is a combination of different types of heaters because all IR heaters don't operate at equal efficiency in all wavelength regions.

Heater Types. Both electric and gas heaters are available.

Electric Heaters. These heaters are designed in vari-



Case history:

Preheating aluminum castings and forgings

A powder coater wanted to increase production with the least amount of change to its existing line and at the lowest installation cost. The company powder coats irregularly shaped aluminum castings and forgings up to 3 feet long with cross-section profiles up to 16 inches. They weigh up to 60 pounds.

The parts were hung on 2-foot centers on the conveyor and preheated to gel, or melt, a black polyester powder before they entered a gas-fired convection oven. The finished powder thickness was 2 to 3 mils. The convection oven provided a 20-minute cure at an average line speed of 6 feet per minute (a 120-foot-long conveyor path).

Cure time reduced. After testing the product with a flat-panel, medium-wavelength electric infrared heater, testers recommended a 3-minute IR preheat before convection curing to raise the temperature of heaviest part to 375°F to 400°F, which gelled the powder. The powder on lightweight parts gelled in

less than 90 seconds. The IR preheat-gel oven allowed the company to increase air velocities in the convection oven without increasing gas consumption. As a result, the company reduced cure time to 8 to 10 minutes.

Line Speedup. The combination cure system also achieved a production speed of 10 feet per minute when processing the heaviest part, with a 30-foot IR oven consuming an average of 180 kilowatts per hour. The company batched parts for the best system efficiency.

The powder uniformly gelled in the IR oven, even in hidden areas of the casting, because of the excellent conduction properties of the aluminum. Other base materials, such as brass, copper, and even steel, exhibit similar results. Such applications are candidates for total IR preheat-curing systems.

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ous configurations, including bulb, metal sheath, ceramic, flat panel, and short- and medium-wavelength tubular quartz. Many IR heaters—such as short- and medium-wavelength tubular quartz and metal sheath—require external reflectors to direct the energy to the product. These reflectors may need maintenance to keep them clean for the best efficiency. Other heaters—such as flat panel and tubular quartz with integral reflectors—are maintenance free.

Gas Heaters. Catalytic panel heaters are available that operate in the long-wavelength regions with water and carbon dioxide as the only by-products of combustion and relatively low energy outputs equivalent to 10 to 12 watts per square inch electric. Gas ceramic face, or matrix, burners operate in the medium-wavelength region with energy outputs that equal electric (50 watts per square inch and more). Catalytic gas heaters are safe to operate in hazardous (explosive) environments such as a Class I, Division II, Group D environment, which allows them to be placed closer to a powder application booth than other types of heaters.

Controlling the curing process

Electric systems may provide a finer process control than gas systems. Electric heaters can be built to pro-

vide tighter tolerances of uniformity over their surface area than gas heaters. Gas heaters are limited in their range of control, with a minimum output requirement to sustain combustion. Typically an electric heater can have a full range of control from ambient temperature to maximum operating temperature; a gas infrared heater may be limited to a turndown ratio of between 3 and 5 to 1.

When an IR oven is used as a preheat-gel oven before a convection oven, the first few feet will quickly bring the coated product up to the gel temperature. With the powder gelled, the convection oven can then hold the product at temperature for cure, using air at higher velocities than would have been safe during the initial stages of processing with loose powder on the part. The higher air velocity allows the convection oven to operate at increased efficiency.

Figure 5 compares the warm-up rates of typical parts in an IR oven with those of a standard convection oven. New systems can be designed with IR preheat and convection cure sections to reduce floor-space requirements.

Infrared preheat-gel ovens can be precisely controlled from top to bottom, ensuring a uniformly preheated part. In overhead conveyor applications, vertical zones

Case history:

Preheating clear and colored powders on brass bathroom faucets

A manufacturer of contemporary bathroom fixtures requires clearcoats to protect the brass appearance on faucets and colored coats on brass to match the fixtures. The manufacturer uses polyester and epoxy powders to coat brass parts of varying shapes, sizes, and masses. Parts are hung on trees one row deep on an overhead conveyor. Like-mass parts are batched together; colors are mixed from one tree to another in preparation for curing.

The heaviest parts, with clear powder coatings, required a 60-second gel time. Light parts had reduced gel times. Colored powders, because of their pigment, reached gel temperatures up to 20 percent faster than the clear powders.

Floor space saved. As part of a new installation, the company specified a 10-foot-long, 5-foot-tall electric IR preheat

oven to accommodate a 4-foot-tall part tree. The oven was rated at 150 kilowatts, with an average power consumption of 100 kilowatts per hour. Production speed was designed for 10 feet per minute. The IR preheat was followed by a 30-foot-long gas-fired convection oven to complete a 3-minute cure.

The combination IR preheat and convection oven required only 40 feet of conveyor. A typical convection oven alone would have required up to 10 minutes dwell time with an overall length of 100 feet. The combination system saved 60 feet of costly conveyor and valuable plant floor space, and reduced overall operating costs.

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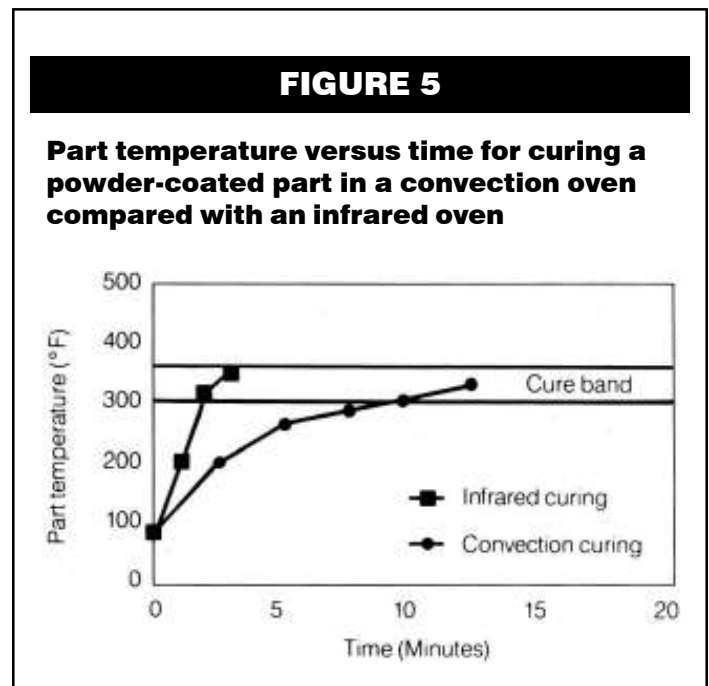
are designed into the system based on the part height, weight distribution, material type, and so on. Typically a bottom zone, one or two midzones, and a top zone are recommended. Vertical zoning provides an additional benefit: If the product height mix is great, short parts can be batched and the bottom zone(s) can be turned off, which saves power.

Process control systems should be designed for repeatable results. Unlike convection ovens where an ambient temperature is set and the product is gently raised to that temperature over an extended time, IR ovens rapidly raise the part temperature, which put demands on the system process controls.

Ambient air control is unsuitable for IR ovens. Open-loop controls with preset power levels or closed-loop controls that measure the emitter or part temperature with noncontact pyrometers give accurate and repeatable results. Power controls are available to monitor the open-loop power setpoint and compensate for line voltage fluctuations to maintain constant power output from the heaters. The importance of this type of control applies to both electric and gas IR systems and ensures consistent and repeatable results throughout the year.

Installing an infrared preheat-gel oven

Finishers who have convection ovens with overhead conveyors that are currently processing powder can place an IR preheat-gel oven directly before the con-



Case history:

Preheating metal tubing and sheet metal for office partitions and furniture

As part of a new system, a custom fabricator of office furniture, partitions, and accessories installed an 8-foot-long electric IR preheat-gel oven before an 100-foot-long gas-fired convection oven.

Flexibility required. The fabricator required flexibility in the preheat oven to run mixed parts and powders. Gel temperatures were expected to range from 300°F to 450°F. The company targeted its production speed at 15 to 25 feet per minute. Part heights were to range from 3 to 6 feet. The company planned to batch parts based on their length when hung from the overhead conveyor.

Vertical zoning suitable. The IR oven was zoned vertically so that lower zones could be shut off when short parts were run. For the 6-foot part, the company uses a heated height of 7 feet 2 inches. Cut-off zones provide heated heights of 8 feet, 7 feet, 6 feet, 5 feet, and

4 feet. By using proximity sensors and a programmable controller to check the part sizes before coating, the company can automatically select the required active zone height.

The system also includes a noncontact optical pyrometer to measure the temperature of the part as it exits the IR preheat-gel oven. A programmable controller accepts information from the pyrometer and controls the power to the heaters. Although the system was rated for a connected load of 216 kilowatts, it rarely consumes more than 50 percent of its capacity.

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Case history:

Catalytic gas preheat of steel shelving and cabinet parts

A manufacturer of steel shelving and cabinet parts was curing an epoxy-polyester powder coating in a 60-foot-long gas-fired convection oven at 8 feet per minute. Parts are mostly 14-gauge steel, with a maximum height of 7 feet, a maximum length of 7 feet, and a maximum bent cross section of 4 inches. Parts are typically U or Z shapes.

Catalytic gas-fired IR requested. With orders up, very favorable natural gas rates available at 50 percent of local electrical rates based on BTU content, and concerns over stack emissions, the manufacturer requested an environmentally friendly catalytic gas-fired infrared preheat system.

Laboratory tests showed that the hybrid powder gelled with only a 30-second IR preheat compared with 3 to 4 minutes

in the convection system. The manufacturer could also increase line speed by 50 percent with only a 6-foot IR preheat system rated at 300,000 BTU. Actual consumption would be close to 200,000 BTU per hour based on the average products that would be run.

Overall costs down. With such a short IR system, the manufacturer didn't require and conveyor modifications, and the convection oven completed the cure in 4 minutes. Overall cost per part dropped 20 percent because of the increased efficiency of the convection oven with higher air velocities impinging on a gelled product.

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Q When is an application suitable for an all infrared cure?

A Electric or gas-fired infrared can provide a total cure for many applications. Generally, parts that are symmetrical and can be hung on an overhead conveyor or mounted and rotated on a spindle (chain-on-edge) conveyor are good candidates. Total IR systems can have multiple zones along the conveyor to raise the part tem-

perature to the gel point and then hold the part at cure temperature.

Complex shapes have more hidden areas that need to be coated and cured than simple shapes. In addition, the less conductive the substrate, the more difficult it is to design an efficient total IR cure system. Compromises can be designed into a system. For example, the IR energy levels of the cure-hold sections can be set so low that they simulate a convection oven. Under such circumstances, however, the advantages of IR may not be realized and

you should consider a combination IR preheat-convection oven.

Applications with mixed part sizes or substrates may require total convection ovens. Electric and gas-fired IR ovens are valuable tools for the coatings of today and the future. Rely on your IR equipment supplier to recommend a proper concept based on your production needs.

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vection oven in the entry vestibule or in the first oven section. The best solution depends on conveyor space, production goals, and convection-oven access.

Because the IR preheat-gel oven brings the powder to its gel temperature, it's important that the curing process remain uninterrupted. When the gelled coating reaches cure temperature, polymer crosslinking begins and the properties of the final coating start to develop.

Gaps between the IR preheat-gel oven and the convection oven may actually cause the part and powder to lose temperature, decreasing system efficiency and affecting the final cure. Each type of powder has different tolerances to temperature variations during the cure cycle. As a result, you should consult your powder coatings manufacturer for specific temperature variation tolerances.

In chain-on-edge, or spindle, conveyors, oven setup concerns are similar. Parts being rotated during powder application should be rotated in the IR section to ensure a uniform cure. Heaters may be required on one side or both sides of the conveyor, depending on the part shape, part thickness variations, and powder type. Concentric parts can be preheated to the gel temperature quickly with two-sided and possibly top heat. Vertical side zones can be designed to profile the IR energy emitted onto irregularly shaped parts that may have varying thicknesses.

To get the most use out of your existing convection oven, the IR preheat-gel oven should be placed into the entry vestibule, with any air locks or curtains disabled. The IR preheat-gel oven can extend, if required, in front of the original entry vestibule. A new entry vestibule should be placed in front of the IR preheat-gel oven to provide a buffer to the factory environment.

During the preheat-gel phase, minimal smoke is generated. This allows the IR preheat-gel oven to be connected to the exhaust-recirculating air system of the convection oven, which reclaims energy.

In retrofit installations, the preheat zone of the convection oven should be reconfigured to increase air velocities for greater energy transfer efficiencies. This can be safely done with fully gelled part exiting the IR preheat-gel oven.

In new installations, the IR preheat-gel section can be incorporated as part of the convection oven design, or the convection oven can be specified without an entry vestibule and a low-velocity preheat entry section, which allows you to get a separate IR system. Combination systems are available from both manufacturers of IR ovens and convection ovens. You may choose to independently buy the IR section and the convection section from different suppliers and integrate them into your plant. Either way, you can't go wrong. An IR preheat-gel oven will raise your production levels and add to the quality of the final coating.

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End Notes

1. *The 1995 Finishing Market Study*, prepared by Chilton Publications Research Services, Radnor, Pa.
2. The Infrared Spectroscopy Committee of the Chicago Society for Coatings Technology, *An Infrared Spectroscopy Atlas for the Coating Industry* (Philadelphia: Federation of Societies for Coatings Technology, 1980)
3. Electric Power Research Institute, Center for Materials Fabrication, and Infrared Equipment Association, *Technology Guidebook for Electric Infrared Process Heating* (Columbus, Ohio: EPRI, CMF, IREA, 1993).