Infrared Drying and Curing Systems

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Today's finishes require precise control of color, gloss, texture and surface finish. Cured organic coatings must perform well in the environments where the product will be used. Infrared curing and drying can provide these properties consistently, with easy operator control, fast curing times, precise control, low maintenance costs, and over 50% less floor space.

Infrared radiation can be used in a variety of different applications from drying and curing to preheating before a convective oven. Whether infrared radiation is used in the finishing process of organic coatings on products such as light fixtures, hot water tanks, shelving units, or insulated doors, line speeds can be drastically increased and cost savings can be realized.

How a convective oven differs from an infrared oven is like night and day. At night, if a car remains outside in a driveway, it eventually becomes the same temperature as the surrounding air. The air slowly exchanges energy with the outside of the car body during molecular collisions of the air molecules with the surface of the car. During the day the air temperature could be exactly the same, however, the car rapidly heats up well beyond the air temperature because the sun's radiation can heat the car body faster than the air can cool it.

The above applies to finishing systems as well. Radiation can transfer heat energy to a product at a much greater rate than convective air. Much time is spent bringing a product up to its curing temperature in a convective oven. Infrared radiation drastically shortens the time necessary to get the coating to its curing temperature, and then holds it there for its curing cycle. Figure 1 compares product temperature with time for curing a powder coated product in a convection oven and in an infrared oven.

![Figure 1](image-url)
Typical Applications

The following are some specific examples of how infrared curing systems were engineered to meet certain production requirements:

Curing Powder Coating on Specialty Lighting Fixtures. With the change from a solvent-based paint spray system to modern powder coating technology, the manufacturer wished to update an old gas fired convective oven that could not handle the higher energy requirements necessary for curing powder.

A tunnel oven was designed using flat panel medium-wavelength emitters within an insulated enclosure. The oven fully cured the powder coating on the outside and inside of the fixtures in just over two minutes. The system used approximately 120 KW of power at line speeds of up to ten feet per minute and now produces in two days the production that once required a full week.

Drying Paint on Hot Water Tanks. Applying a high-solids, solvent-based paint, the company wished to increase the speed of the paint line. Existing equipment was a 60-ft-long, gas fired convection oven, with a production speed of three feet per minute.

A two section infrared oven was designed, utilizing two types of infrared heaters. The first section quickly raised the temperature of the paint and started the solvent evaporation. Medium-intensity quartz tubular heaters were chosen. The second section help the product at the final bake temperature, ensuring good flow and cure.

The system was 13 ft long and consumed 85 kw/hr of electrical energy. Through the use of infrared radiation, the company saved over 45 ft in production space and increased line speed over 100 pct. Unit operating costs were slightly less than with the original oven.

Preheat to Convective Oven for Curing Powder Coating on Shelving Units. Commercial supplier of shelving units needed a 40% increase in line speed to keep up with production orders. Existing equipment included a electrostatic powder coating booth with a 100 ft long gas fired convective oven. Line speed was 10 ft per minute and an increase to 14 ft per minute was necessary.

A 8 ft infrared section was added in front of the existing unit to meet the requirement. An additional 288 kw of energy was needed to power the flat panel medium-wavelength emitter preheat unit.

An infrared preheat to a convective oven can be used to gel a powder coating, preventing blow-off. Once the powder has gelled, the air velocity in the convective oven can be increased yielding higher efficiencies.
Dry and Cure High Solids Water-Based Coating on Insulated Doors.

New V.O.C. reduction requirements forced the factory to replace solvent based coating with high-solids water-based finish. The new paint needed more energy than available from the existing long-wave infrared oven system.

A system was designed to meet the higher energy requirements of the water-based coating. The upgraded infrared system had medium-intensity, medium-wavelength quartz tubular emitters installed within an insulated enclosure and a blower to provide exhaust for the released water vapor.

The quartz tubular emitters were selected for their ability to heat water-based coatings efficiently. The quartz tube surrounds the emitter coil and allows air flow around the heaters without cooling the emitter.

Infrared Theory

Every organic coating has a particular energy spectral absorption curve. There will be peak wavelengths where the coating absorbs very well, and valley wavelengths, (off-peak wavelengths), where it is almost transparent to the applied energy. These peaks and valleys correspond to particular ranges of emitter temperatures. Most coatings have absorption peaks falling between the wavelengths of 2.5 and 4.0 microns.

Infrared radiation, with wavelengths expressed in microns, can be accurately measured, controlled, and applied to the product. Figure 2 illustrates the electromagnetic energy scale in which infrared is centered.

Any mass whose temperature is above absolute zero is radiating infrared energy. It is not until that mass is heated well beyond the temperature of a different mass that the radiation from the hot mass to the cooler mass becomes meaningful. Generally speaking the amount of radiation available is determined from the difference in absolute temperatures of the two masses raised to the fourth power multiplied by a constant.

Figure 2
To put it simply, an infrared heater will exponentially produce more radiation as the emitter temperature is raised. Figure 3 shows the relationship between emitter temperature in degrees Fahrenheit and radiation in watts per square inch, as well as wavelength of the radiation measured in microns.

![Figure 3](image)

Long-wave, medium-wave and short-wave infrared energy may all be used, in part or in whole, in the drying and curing processes. The most efficient type of energy being determined by the actual process requirements. Long-wavelength infrared energy is emitted at wavelengths of greater than 4.0 microns, with energy densities of below 15 watts per square inch. Medium-wavelength infrared energy is emitted at wavelengths between 2.0 and 4.0 microns, with energy densities of 15 to 60 watts per square inch. Short-wavelength infrared energy, which is also known as high intensity infrared, is emitted at wavelengths between 1.0 and 2.0 microns, with energy densities of up to 200 watts per square inch.

A heavy metal part that is to be coated with a high-solids coating or a powder coating may require either long, medium or short-wavelength infrared energy, or some combination, to provide maximum efficiency and desired product quality. Long-wavelength infrared energy would be absorbed slowly by the coating, at near the same rate as the transfer of heat in a convective oven, and eventually heat the whole product mass. By using medium-wavelength infrared energy, the coating will directly absorb the majority of the available energy, with small losses by conduction to the metal substrate and some losses by convection from the coating to the surrounding air. Short-wavelength infrared energy would tend to rapidly penetrate the coating and heat the substrate directly, which in turn would heat the coating by conduction. (See figure 4)

![Figure 4](image)
Assuming that none of the approaches will cause bubbling, blistering or surface skinning, the medium-wavelength system that heats the coating directly will generally require less operating energy, since the mass of the substrate will not act as a heat sink. However, if the coating is prone to blistering and surface skinning, air must be introduced with the medium-wavelength infrared system, possibly reducing the efficiency. Alternately, a short-wavelength system will penetrate the coating, possibly preventing surface skinning, heating from the inside out, resulting in the desired finish quality.

Long ovens utilizing long-wavelength, low temperature heaters are sometimes the only alternative. However they do not offer the efficiency available in the medium or short-wavelength systems, due to their low infrared output and convection losses.

Since different infrared heat sources produce different effects, the process should be carefully planned and specified. Choosing the wrong infrared system for a particular product can result in a system that wastes production floor space, demands excessive operating energy, produces inconsistent quality, and causes defects in the product finish.

Types of Heaters

The variety of infrared heater products manufactured fall into many different categories, three groupings will be used to make comparisons easier:

1. **Short-Wavelength/High-Intensity.** These heaters consist of quartz tubes with tungsten filaments in a halogen atmosphere. They have normal internal filament temperatures of approximately 4000°F at emission wavelengths of 1.0 to 1.2 microns. Watt densities can be provided up to 200 watts per square inch and a mean life expectancy is about 5000 hours.

   Manufacturers have configured systems with gold reflectors behind the heaters, gold or ceramic coatings on the back side of the heater or mounting arrangements in front of ceramic refractory plates to direct the energy towards the product. External reflector systems provide good control of the radiation spread, but may need periodic cleaning or replacement. Heaters with gold coatings have temperature limitations and when used with cooled housings provide a narrow band emission requiring precise process control.

   Systems with ceramic refractory plates behind the heaters sometimes will introduce air through these plates and between the heaters. This arrangement provides not only a primary emission from the heater itself, but a secondary emission from the refractory plate in the medium wavelength region plus convective heating by the air, yielding a more versatile and forgiving system.

2. **Medium-Wavelength/Medium-Intensity.** This group contains the largest variety of heaters, both gas and electric. These heaters emit energy between 2.0 and 4.0 microns, with energy watt densities of between 15 and 60 watts per
square inch. Operating temperatures can be reached of up to 1900F, with mean life expectancy of 10,000-25,000 hours, depending on heater construction.

Included in this group are wide-area, flat-type heaters, quartz tubular heaters metal-sheath heaters, metal-faced and ceramic types, and a variety of different gas burners, such as simple burner strips or flat matrix burners. These can provide infrared radiation to the product, some more efficiently than others, with minimal convective losses unless used as a secondary emitter. A secondary emitter is one whose primary function is to heat the air in a convective oven while providing the additional benefit of infrared radiation as a secondary function.

Wide-area, flat-type heaters can have a quartz plate, ceramic face, or woven cloth face of either silica or fiberglass over the emitting coil to help provide a uniform output. These flat heaters can be accurately controlled and emit energy in the region absorbed most readily by liquid and powder coatings.

Metal-rod heaters are often used with metal reflectors to direct their energy toward the product. Depending on the coating, periodic maintenance or replacement is required. Tubular quartz heaters in this group have their heating elements open to the air. Some make use of external metal reflectors, others have a reflective coating on the backside of or a special refractory within the heater. Quartz heaters without external reflectors can be closely packed, giving higher watt densities and smaller controlled zones.

Within this group there are two types of electric heaters: those that emit their energy from the surface and those that emit from within, through a "window". All quartz type heaters have an advantage of emitting from within, with the quartz acting as an insulating window, minimizing convective losses. Quartz acts as an insulator for the emitting coils and is virtually transparent to infrared energy in the medium-wavelength range. On the other hand, the metal-sheath, metal-faced and ceramic heaters emit energy from their surfaces, so that more of the energy is converted into convective energy, which is less efficient in heating the product.

Gas heaters can be used to provide a wall of infrared radiation or used to heat the air in a convective oven and radiate energy to the product as a secondary function. These heaters burn gas either at the surface of a matrix material or on the face of a burner. Catalytic gas heaters operate at temperatures below 850F which puts them into the third category of infrared heater products, although they offer the same efficiencies and processing times as many of the medium-wavelength heaters.

3. Long-Wavelength/Low-Intensity. This final group includes heaters that emit energy at wavelengths of 4.0 microns and longer, with energy densities below 15 watts per square inch. Operating temperatures can be reached of up to 850F, with mean life expectancy of 15,000-20,000 hours.
Construction types of the electric emitters include metal-faced panel heaters, fiberglass emitting surfaces, or ceramic cylinders mounted in concave reflectors. The gas heaters that fall into this category are catalytic infrared heaters that chemically catalyze the gas on a surface instead of burning the gas to produce infrared energy.

Generally these types create a combination of convection and low-intensity infrared suited for coatings that must have longer bake times due to surface or coating characteristics, and where the user wants a system that is more efficient than a standard convective oven.

This group tends to be less expensive in initial cost than the two other groups, but it is unable to provide the same efficiencies in energy consumption and savings in floor space possible with the medium- and short-wavelength systems. Metal-face-panel heaters are constructed in strips with the heating element within and commonly provide lower available energy outputs than do some of the other types. Ceramic heaters are available in building block sizes, and require reflectors to direct their energy to the product.

Summary

Infrared radiation can be used in curing and drying processes to provide precise control of color, gloss, texture and surface finish of today's finishes. The consistency of infrared radiation to enable organic coatings to perform well in the environments where the product will be used is a function of the controllability of the radiant output and temperature of the emitter.

When the peak output emission of the emitter matches the peak absorption of the coating, heat energy is efficiently transferred. The temperature of the infrared heater can be controlled within one degree of the determined operating set-point. This means that day in and day out infrared radiation can be used to accurately and precisely heat, dry, and cure modern organic coatings.
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