IR CURING SHOPTALK

Infrared Equipment Division of IHEA

This column is provided to you by members of the Infrared Equipment Division (IRED) of the Industrial Heating Equipment Association (IHEA). The group includes infrared (IR) curing equipment suppliers from throughout North America. We publish the column three times a year to give you the latest information about IR curing techniques and equipment. Contact information is at the end of the column. Most IR manufacturers offer testing for free or for a fee. Any IRED member can assist you in finding solutions to curing problems and best practices for finishing of coatings. This issue's column was submitted by IRED member William E. Pasley, The Southern Co., Atlanta.

Powder curing: Some lessons learned

As I near the end of my career, there's time for reflection about various aspects of my work. I've been involved with powder coating applications in a variety of product lines for well over two decades. In this article, I'll share with you some things that have struck me as opportunities for improvement in the heating/curing of powder coatings.

One: Using infrared (IR) only

For years, man-made light was only available as a result of some heated material that emitted light. Then came the discovery of light-emitting phosphorus and ultimately LED solid state devices. Unfortunately, IR emitters haven't seen a similar progression in breakthrough solid state devices like LEDs. The emitters currently used for powder curing are all producing radiant energy as a function of the temperature of the material. There are ultraviolet-curable (UV-curable) powders, but I won't address those in this article.

Creating the IR. Here are some common questions I've been asked over the years about IR cure technology.

Is the fuel source significant? I often get asked if it makes any difference if the radiant output is from an electrically heated emitter or a gas-fueled (combustion or catalytic) emitter. The answer is that the physics of radiant output doesn't care. As long as a material is heated to the same temperature with either fuel, the radiant output frequency (long, medium, or short) is the same.

What about emitter construction details? If operating temperature makes "all equal," then what else differentiates in the choice of an emitter? For both gas and electric, there are several different types of emitter construction. You can find ample descriptions of these in literature, such as IRED's *Infrared Handbook*, available at www.ihea.org/ired_handbook.cfm.

How efficient is IR? An obvious key consideration when choosing an emitter is its capability to efficiently provide radiant heating. Physics dictate that the higher the operating temperature of an emitter, the greater the amount of total energy that is converted to radiant. Conversely, the lower the temperature one operates at, the greater the amount of convection heat that is produced. This can be seen in the following equation:

Power in = Radiant out + Convection out
or
Power in = $k(T)^4 + cT$

You can see that the higher the temperature T (in kelvin), then the greater the percentage of input power that goes into radiant energy. The other variable, cT, is convective heat, which may be considered "wasted" according to how an oven is designed.

How much horsepower? Intensity (flux density) and surface area. The other characteristic of concern is the amount of radiant energy that can be produced per unit area. Some emitters use heated sheet metal walls of ovens as emitters. These have large surface areas but small radiant output densities. On the other end of the continuum are much smaller high output electric emitters. These can be small due to the large radiant output number the T^4 component becomes.

A good reference is an article in *Powder Coating* magazine titled "Measuring the radiant efficiency of infrared curing heaters," published in November 2006[1]. A chart

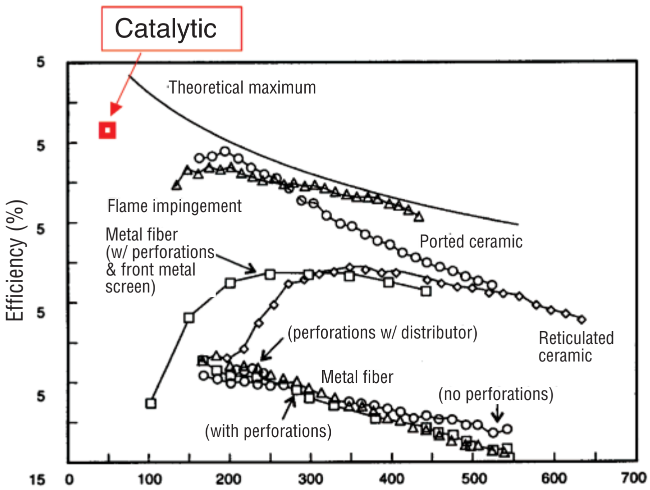
(Figure 1, shown here; Figure 7 in the 2006 article) titled "Comparing the radiant efficiency of catalytic IR heaters with that of other IR heaters" shows various commercial gas radiant emitter types and their efficiency as a function of the combustion intensity. In all cases shown on the chart, the efficiency is reduced as the intensity is increased. The article doesn't discuss the mechanism causing this. It's my understanding that there isn't a comparable reduction in efficiency versus intensity for electric emitters. The implication is that if you want more output with gas-fired equipment, you will pay an efficiency penalty if you do it, whereas, for electric, there doesn't appear to be this penalty.

Putting the IR to work. You don't necessarily have to follow published curing specifications. In the article "Cure Dynamics of Powder Coatings," published in November 2008[2], the author states (in reference to heating of the molecules and atoms in the powder) that there are more collisions, and therefore a faster reaction occurring at higher temperatures, which means shorter cure times for powder coatings. The author goes on to say that cure times for powder coatings were reduced from 27 minutes to 8-9 minutes for urethane-based polyester and from 32-33 minutes to 10 minutes for the triglycidyl isocyanurate-based (TGIC-based) polyester when temperature was raised from 350°F to 400°F. All of this is said to make an obvious point, that the curing of a powder coating is directly related with the temperature being applied to the powder. The numbers indicate a three-fold reduction in cure time with the 50°F temperature increase.

I've personally conducted or been associated with many tests wherein the published cure schedules for the powder were significantly longer than the test times required. Many tests have shown curing of test panels in a minute or two. One of the best examples of this is the rapid curing of oil filters in many commercial installations requiring much less than a minute for curing.

FIGURE 1

Comparing the radiant efficiency of catalytic IR heaters with that of other IR heaters



Source: Speyer, R.F., Lin, W.-Y., and Agarwal, G."Evaluation of Commercial Gas Radiant Emitters," *Industrial Heating J.*, June 1997, pp. 53-58.

Another area related to the curing specs is the statement that the substrate must reach a certain temperature. A classic case study titled "Infrared Curing of Coatings on Heavy Parts," available on the Pollution Prevention Regional Information Center (Region 7) Web site[3] involves the powder coating of engine blocks. Using high-intensity IR, the powder was successfully cured while the mass of the blocks stayed well below the recommended cure temperature of the powder. Perhaps the substrate just beneath the powder had met specs; however, the point is, heavy parts may provide room for temperature gradients within.

Powder vendors are willing to perform curing tests on their coatings that go outside their standard published cure schedule. Don't be afraid to push the envelope in this area.

Matching the emitter wavelength to the absorption characteristics of the powder. Is this always best? Certainly this makes sense, at least on the surface, so to speak. In reality, it's more complex. In some previous investigation into powder curing variables, we learned that you must broaden your perspective on what you are trying to accomplish. Obviously, the objective is to have the powder coating absorb as much energy as efficiently as possible. Some findings to consider are as follows:

- If your powder contains even a small fraction of a percent of carbon black, the powder will absorb IR equally well, no matter what the wavelength of the emitter.
- If you're trying to cure a pure white paint, short-wavelength IR is mostly reflected.
- Even though a longer wavelength emitter may produce output more equal to the absorption curve of the powder, the radiant output may not be sufficient to accomplish the cure in the needed time. Because of this, a higher intensity IR source may be needed to accomplish the cure. This can be done as described in a paper published on this subject "Powder Curing Using Infrared Heating," presented at Powder Coating '94, and available at the Pollution Prevention Regional Information Center (Region 7) Web site[4]. The point is that, even though the absorption may not be as efficient, there is sufficient radiant at the needed wavelength to do the job in the allotted time.

Two: Combining convection and IR

There seems to be a growing acceptance of the practice of using IR heating in combination with convection heating. For several years, there has been a common practice of placing a booster IR in front of an existing convection oven. This additional heat in a small footprint has allowed companies to increase their production line speeds with the added benefit of reaching the gel stage before reaching the air currents in the convection oven.

Even more impressive is the use of IR heaters inside of convection ovens. Many articles and case histories have presented examples of the benefit of this approach. Most impressive to me is the capability this gives the company to use one oven to cure parts in various sizes, masses, and thicknesses while maintaining a constant conveyor speed with random, not grouped, sequencing of the different parts. All of this is accomplished by easily controlling the output of the IR heaters.

Equally impressive is the capability of curing parts with a wide range of thickness of metal on the same piece. The IR heat provides the needed extra heat to the thick sections while the convection heat keeps the thin sections from over-heating from the IR. A previous shoptalk article described this in detail[5].

Three: Realizing exhaust savings

Do you realize that in many convection curing ovens, there's a lot of "tradition" related to how exhaust calculations are done? These can cost you money every hour you're running your oven. I'll enumerate a few next:

- Gas-fired package burners have traditionally been sized based on the maximum-ever expected heat load that may be introduced into an oven. How often do you think this occurs? Perhaps in a continuous oven it may be common, but in batch ovens probably not so common. This leads to oversized burners, and by the way, additional exhaust to get rid of products of combustion (based on max output of the burner) for the larger burner.

- No matter how much the gas burner is turned down, the exhaust fan continues to exhaust as if the burner was on at 100 percent.

- Purging requirements dictate four air changes before ignition can begin. Did you know that one way the purge cycle can be shortened is to oversize the exhaust fan? In a recent project, I discovered that this was the case and that the "oversizing" caused 40 percent more exhaust than was required every hour the oven was running.

- Did you realize that the National Fire Protection Association (NFPA) 86 Standard was changed in the current edition to allow you to recalculate the amount of exhaust air that is required in a powder curing oven? Historically, the calculation was prescribed with the use of 9.0 percent xylene by weight, but now you can use actual volatile organic compound (VOC) content from the material safety data sheet (MSDS), which is often less than 1.0 percent. A previous shoptalk article discussed the change[6].

In an upcoming shoptalk article, we'll present a case study from a research project that is just getting started. It will address the impact of varying the traditional operations as just described.

Four: Reversing the always-been-done-that-way attitude

Here's a brief story to describe this. I will leave the company unnamed, but it was an automotive radiator plant that was sole supplier to eleven assembly plants. When I visited the plant, I asked about a new, large convection oven that had just been installed. In fact, it was so large it had to be designed in a "U" shape due to its length. It was approximately 80 feet long by 10 feet tall by 10 feet wide. I asked what it was going to be used for. I was told that the automobile manufacturers didn't want their customers to see the shiny aluminum radiator through the grille of the car, so they wanted one side of the radiator powder coated with a black paint. I really was speechless for a moment. I asked why it was designed so large, etc. The answer was that it was a safe bet, they knew it would work, and no one would get in trouble for sticking their neck out to try something new.

To this day I would still offer the same bet I offered that day as I considered the incredulous/incredible waste of resources: "I would bet you one month's pay that I could have done the job with a low profile IR oven that had the footprint of approximately 20x5 feet." I'm sorry to say that the plant is no longer in business.

Thinking out of the box. The previous observations were made to help you understand that there may be other things to consider as you seek the most efficient powder cure that's needed. You owe it to yourself to try different things—whether it's the way in which you produce the IR, how you may combine it with convection, or whether you use the best "matched" emitter with the absorption curve of the powder.

What all of the above has convinced me of is the following: The best way to see if a variation from "standard" will work is to try it. Arm yourself with as much understanding as you can gather and then run your own tests. Include your paint vendor in what you're doing and get confirmation that you have an adequately cured product. Threefold, or more, reduction in curing times and similar benefits in reduction of your oven footprint are just too great to not be pursuing! **PC**

Endnotes

1. Available at www.pcoating.com by clicking Article Index, Subjects, Curing, and scrolling to Technical Articles.
2. Ibid.
3. Go to http://infohouse.p2ric.org/ref/09/08998.pdf.
4. Go to http://infohouse.p2ric.org/ref/25/24276.pdf. (See figures 8 through 11).
5. See *Powder Coating*, August 2011 (digital only) "Maximize your convection oven by using infrared," p. 35; or go to http://ihea.org/documents/IR-Shoptalk-8-11.pdf.
6. See *Powder Coating*, September 2010 "New changes to NFPA standard help reduce your oven heating requirements," p. 12; or go to http://ihea.org/documents/IR-Shoptalk-0910.pdf.

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