IR CURING SHOPTALK

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 members Joel P. Watts and Scott E. Bishop, The Southern Co., Atlanta.

Improving your powder curing process: Convection efficiencies and infrared additions

Infrared Equipment Division of IHEA

As a supplier of energy to many industrial customers having convection ovens, the Southern Company and it's affiliates, Alabama Power, Georgia Power, Gulf Power, and Mississippi Power, have assisted these customers in recent years to improve the efficiency performance and design of these ovens. The primary focus has been on preheating and other productivity improvements related to powder curing. One of many resources available to our customers is the Technology Applications Center (TAC), which is a resource center with a primary mission of offering energy efficient solutions to improve manufacturing processes. (See Figure 1.)

Powder coating and curing have been featured technologies since the inception of the TAC in the mid-80s. In this area we have focused primarily on demonstrating technologies related to convection, infrared (IR), ultraviolet (UV), induction, and combinations of these as heating/curing technologies. The TAC concept provides these technologies to the manufacturer for testing, demonstrating, and evaluating the curing of powder applied to their actual production parts. The choice of technology is always dictated by performance. The focus is always on what is best for the customer, with the ultimate goal of helping the customer grow and remain healthy in this competitive global market.

In parallel with the technology demonstrations, there has been an emphasis within the TACs on other means of improving and demonstrating energy efficiency for our convection oven customers. As part of these efforts we have developed a checklist to improve the efficiency of convection drying/curing ovens that customers should consider. Much has been written on the obvious things, such as insulation, infiltration, openings, burner tuning, etc. The literature is replete with various suggestions and checklists. This article focuses on some of the less obvious things that may have been overlooked as you considered improving the operations of your existing convection oven.

Oven design data

Convection ovens, without heat recovery, have always been known to be inefficient in terms of energy usage.

FIGURE 1

Southern Company's Technology Applications Center (TAC) in Calera, Ala. Southern Company has another TAC in Georgia.

Useful heat allows the product to reach the desired setpoint temperature and hold for the appropriate dwell time to cure powder coatings. Within a convection oven, heat that is absorbed and lost can be attributed to many factors that include but are not limited to the following: conveyor and rack heat absorption; heat losses from the walls, floor, and ceiling; and in the case of continuous ovens, heat loss through the silhouette openings.

The energy that makes it into your product can be as low as 15 percent of the original Btus introduced into your oven. All these "loading" factors are calculated to determine the required Btus when sizing your convection oven heating source. Another important calculation when sizing a convection oven is the makeup air loading. Makeup air, as required by NFPA[1] 86 guidelines, will add Btus to the loading calculations. We will take a look at this requirement later in this article.

It is important to review the original calculations used to size your convection oven. This will assure that calculations are still valid with the current operation of the oven. Following are some questions you should consider:

1. Are the heat calculation requirements still valid?
   - Is the conveyor the same or has a lighter conveyor since been installed?
   - Have the racks been re-designed over the years to carry your product?
   - Has rack density reduced the number of racks used? Has the material weight in your product changed? Has the part geometry changed?
   - Is the burner sized for the current process? Exhaust requirements are based in part on the maximum burner output.
   - Do you need as much heat as the original design called for? A more efficient oven combined with a re-design of the heat requirements could lead to a smaller burner package.
2. Have you changed the type of coating or coating suppliers since the original commissioning?
   - Have lower volatile organic compounds (VOCs) affected required heating and/or exhaust fan speeds?
   - Has the time at temperature changed? Perhaps a lower-cure powder coating is now being used?

On several occasions, even with ovens that are less than two years old, we have found that the customer is not operating the ovens as initially planned. The differences range from different operating temperatures, different dry/cure times, and various production rates. All of these can impact the efficiencies of the original design.

Exhaust design data

The makeup air requirement mentioned earlier is a loading calculation that adds Btus. With makeup air, you now have the need for exhaust requirements for the byproducts of combustion, in the case of gas-fired ovens, and the calculated ventilation for removing VOCs released during the powder curing process. The majority of powders within the industry today will range in VOC content from 0.3 percent to 1 percent.

The proper exhaust calculation is critical to providing a safe operating oven. Too little exhaust can give you a safety hazard; too much exhaust will waste energy. It is this exhaust loss that has been the primary area of focus at the TACs to verify that the calculations on paper are seen in real applications, reflecting the new NFPA 86 standard change to exhaust calculations for powder ovens. As a reminder, the amount of energy contained in exhaust air can be calculated as follows:

Btu = (Flow Rate) x (Time) x (Density of Air) x (Specific Heat of Air) x (Delta T in °F)

Using standard conditions, this number then becomes:

Btu = (cubic feet/minute) x (1 hour) x (60 minutes/hour) x (0.075 pound/cubic foot of air) x (0.24 Btu/lb °F) x (ΔT in °F)

An example calculation for exhaust losses: 750 cfm x 60 minutes x 0.075 lb/cf x 0.24 Btu/lb °F x 300°F delta temperature from ambient to oven set point = 243,000 Btus/hr

Note: These calculations may vary with operating conditions. See NFPA 86 for more detail.

Next, although the exhaust may be considered part of the oven design, it needs to be examined separately in more detail. Some questions for exhaust sizing that need addressing are

1. Are the exhaust calculations still appropriate?

The last review cycle of NFPA 86 changed the method of exhaust calculation for powder curing ovens. The standard had previously prescribed that VOC emissions were to be calculated based on a 9 percent by weight equivalent to Xylene. The 2011 standard now allows the calculation to be based on the prescribed method or the actual VOCs as shown on the material safety data sheet (MSDS). The September 2010 issue of the magazine published an article "New Changes to NFPA standards help reduce your oven heating requirements." The article describes in detail the changes to the standard and then discusses the potential energy savings related to this change. In addition, tables of typical powder paint VOC content were shown. They showed that most powder paints have much less VOCs than the prescribed 9 percent Xylene method.

2. How was the purge cycle originally designed, and how does this correlate to the operating schedule of your oven?

Some designs over size the exhaust cfm to reduce the length of the startup purge time. This same cfm exhaust is then used for all the operating hours of your oven. This wastes energy for every hour of operation. If your oven falls into this category, a simple solution is to place a variable speed drive on the exhaust motor. This would allow you to run the exhaust at a high volume cfm to accomplish the "fast" purge and then place the speed of the exhaust at a lower set-point based on the product being cured and NFPA 86.

Current testing

Two different demonstrations were performed by the TACs regarding the implementation of the newly revised NFPA 86 exhaust standard. One demonstration, performed at Alabama Power's TAC, used a 300 kilowatt (kW) electric convection batch oven. The other demonstration. located at a foundry in Alabama, was done on a 500,000 Btus gas convection batch oven. Both demonstrations included retrofitting a variable speed drive on the exhaust motor and measuring various parameters, including electric usage of the exhaust fan, electric/gas consumption of the oven, oven temperature, and part temperature. Tests were repeated numerous times with both full exhaust (as initially designed) and with a controlled exhaust via a variable speed drive.

Although the field testing is still on-going, initial results are very promising. The data shows a potential to reduce oven gas consumption by 20 percent to 30 percent during operation while maintaining oven temperature and without affecting the part temperature profile. The complete results will be shared in a future article once testing is completed.

IR additions to convection ovens

Once you have addressed the oven and exhaust designs, and you are still in need of some process improvements, you may consider the addition of IR heat to your convection oven. Several presentations and articles have been written regarding the concept of adding IR as a booster before the convection oven or even inside the oven. There are definite benefits that can be obtained with IR, and we will explore some of these next.

Twofold concept. The concept of adding IR to an existing oven includes two separate application areas.

IR on the front of the convection oven. This first area is often referred to as a *booster IR oven*. Additional heat on the front end of most curing ovens can start the powder gelling process as well as provide a head start on the overall part heat up. An added benefit is that the powder will not blow off the parts as they enter the convection section. This process can reduce quality defects, improve throughput, and reduce costs.

IR on the inside of the convection oven. The second area deals with the same need for additional heat but in a different way. You have probably heard that IR heat can burn parts, so you must be careful with how much you use. The "too much" term in the trade is called *infrared intensity*, or *flux density*. This second area of using IR with a convection oven is that of actually placing the IR heaters inside the convection oven. The location of the heaters provides a twofold benefit. The IR intensity is sufficient to provide the additional boost (similar to the booster IR oven) while the recirculation airflow provides a "cooling" component to those parts that may tend to overheat.

Typical applications. Many installations of booster IR ovens are in operation, and much has been written about the effectiveness of this concept. Placing the IR heaters inside the convection oven is a somewhat newer application, however. This application has been very successful in systems wherein parts with multiple thicknesses of material must be cured. Obviously, this can be done in convection-only ovens. But, if increased throughput is needed, the addition of the IR heat is a good way to go. Likewise, it is an excellent concept with just-in-time production, which requires various sizes and mass of parts to be randomly conveyed through the oven. With proper controls, these parts can each be cured with their own recipe of IR heat intensity. For a full discussion of the application of IR in convection ovens, see the August 2011 issue of the magazine. The article is titled "Maximize your convection oven by using infrared."

Summary

Simple and straightforward actions to save energy eventually add up to some real dollars. Taking care of the "little" things also provides a model for employees to emulate as they go about all of their manufacturing activities. As you move forward with your new level of productivity with IR, why not make sure your existing oven is as efficient as possible. It will be something to be proud of, and it can make you money every hour of operation! PC

Endnote

1. National Fire Protection Association; www.nfpa.org

For more information or to submit a question, contact Anne Goyer, executive director of IRED, at 859/356-1575; e-mail anne@goyermgt.com. See also www.ihea.org/ired.cfm.

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