# POWDER COATING

And other GREEN Finishing Technology

THE AUTHORITY SINCE 1990

November 2012

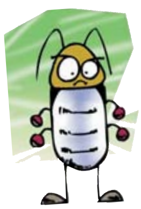
## Oven replacement boosts production

## Curing quality how-to

# Coater's Corner

Chris McKinnon *Aegis Industrial Finishing*

## The quality of cure



When I ask customers what they know about powder coating, the answers I get almost always relate to the durability of the coating. Words such as hard, strong, tough, and durable are used freely. In all these cases, the customers do not realize that they are speaking about one of the most impressive things about powder coating—the **cross-link**.

This article is an introduction to the uniqueness of the cure mechanism in powder coating, the challenge faced by the custom coater when it comes to unique fabrications, tools that all powder coaters should be aware of, and why this matters to your customers. (Note: For the purpose of this article, the type of curing oven being referenced is a natural gas fired convection batch oven.)

**Defining some terms.** Cure? Convertible? Cross-link? Polymerization? Evaporation? To better understand the concepts presented in this article, it is worthwhile to take a moment to define some key terms. In the coatings world, **cure** refers to the process of a coating transitioning from a liquid state to a solid state. Assume that you have a bedframe in your home that has been coated with a lacquer. This lacquer would have cured through the evaporation of the solvents. The coating attained its desired properties of appearance and hardness as the solvent base evaporated. The process of evaporation is referred to as the **curing mechanism**. This is an example of a **nonconvertible coating**: It can be removed after it has dried by use of the same solvent base it was suspended in—its properties are reversible. There are a variety of chemistries available to liquid and powder coaters that are **nonconvertible**, also known as **thermoplastic**.

Now let's consider the same bedframe as being powder-coated. Assuming that it was properly pretreated, racked, and coated, we will examine the curing process. The coating began in powder form, melted into a liquid state (this is often referred to as the **gel**) while in the curing oven, and then, upon removal and cooling, settled into its final solid state. The technical explanation for the cure is that it underwent **polymerization** through forced **fusion cure** (the curing mechanism). More simply, when we talk about cross-linking this is what we are referring to. Through the heat of the oven, the substrate temperature was elevated to the point where a chemical reaction took place resulting in the hardened powder coating.

Once the cross-linking has occurred, the coating will not change back to its original state (although it can be softened and removed through the use of aggressive industrial grade paint strippers). This type of coating is known as a **convertible** coating due to the transformation that takes place at the chemical level in the powder coating. The net result of this process is that powder coating is recognized as being a hard, strong, tough, durable coating.

Sounds simple enough doesn't it? The equation is simple:

Temperature + Time = Cure

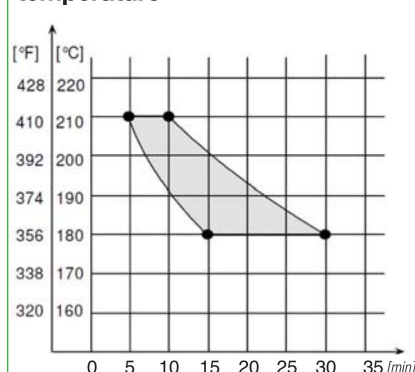
A key ingredient that was left out of that overview of key terms was **temperature + time**. For the thermoset powder coating to properly cross-link, the substrate (in this case a heavy steel bedframe) needs to be held at or above a certain temperature for a defined period of time. If our polyester powder coating requires 15 minutes at 356°F, this does NOT mean that you set the oven to 356°F and put the bedframe in for 15 minutes—you *might* wet out the coating and it *might* look cured, but it will not have any of the mechanical or chemical resistance properties of a properly cured coating.

This combination of time and temperature is commonly referred to as the **cure window**. Every powder manufacturer should be able to provide you with a **technical data sheet** (TDS) that outlines the cure window for their product. As the custom powder coater, it is our responsibility to determine how long the bedframe needs to be in the oven to bring it up to the required temperature and then hold it there. We will base our cure parameters on the cure schedule[1] in Figure 1.

Assume that the bedframe is made from 2-inch x 2-inch hollow structural steel (HSS) with 1/4-inch wall

### Figure 1

**Cure schedule showing time and temperature**



thickness. It weighs approximately 200 pounds and is 6 feet x 8 feet x 3½ feet. As custom coaters, we likely have an idea of the time and temperature required to cure this product from past experience. As it stands right now, for the sake of argument, if our oven is set at 425°F, the product is going to take 20 minutes to get up to 356°F. Looking at our cure window, to achieve full cure of our coating, the bedframe needs to be in the oven for an additional 15 minutes at a minimum.

The challenge comes when we have to allow for the 1/16-inch sheet metal decorative headboard and the solid cast iron bedposts. The varying mass and density complicates the cure process because these two additional components are going to heat up at varied rates—increasing the risk of over- and under-bake.

## Great, now what?

Without the luxury of being involved in the design process, custom coaters must be able to adjust their baking process to accommodate products like our hypothetical bedframe. At 425°F for 35 minutes, you can be sure that the 1/16-inch sheet metal on the bedframe will have heated up rapidly close to the oven's operating temperature, and according to the cure window, we want to be in that temperature range for no more than 10 minutes maximum. Fortunately, there are instruments available that provide us with the capability—and confidence—to properly and repeatedly cure the coatings that we apply.

**Thermal profile data logger.** There are a few manufacturers of these devices, and they offer them in a varying degree of technical sophistication. With the use of temperature probes and the data logger (a small computer that records the temperature and time), the custom coater is able to attach the temperature probes to areas of varying thickness and run the bedframe through a dry run. The resulting data will provide the custom coater with an accurate "recipe" for baking the bedframe. With the device that I am familiar with, when combined with the powder manufacturers cure window data, a value will be produced that gives clear indication if cure has been achieved or not. This device can—and should—also be used to profile your oven on a regular basis to ensure proper temperature balance (this topic will be discussed in a later article). For those powder coaters who run a conveyor line coating system, thermal profile data loggers are also available in a wireless configuration that allows for real time data reporting.

**Pyrometer (infrared thermometer).** This is an invaluable tool that provides the custom coater with real-time data on the floor. The downside is that you have to open the oven and hold the pyrometer 8-inches to 12 inches from the piece to get an accurate readout. Our powder coaters are trained to hit each piece with the pyrometer before pulling it from the oven every time. Caution must be taken, however, to consider the amount of time the piece has been in the oven; just because you get a readout of 360°F on the piece and it has been in for 20 minutes does not mean it is cured, but the process certainly has begun.

(Note: In our tests we have seen a 10° to 15° drop in part temperature when the door is opened to check/remove finished product; while the ramp-up once the door is closed is quick, keep this in mind when checking goods that are baking). A word of caution about pyrometers: Do not cheap-out when purchasing this tool. I have seen devices that go out of calibration relatively quickly, and if this is your main source of temperature data, it must be accurate.

**Eyes.** The powder coater is the person on the floor who is directly responsible for the cure of the coating on the customers' goods. When observing a finished product, if it looks "wet" then it is likely not fully cured. Furthermore, if discoloration is apparent after the coating has cooled down to ambient, then it is likely that the product was left in the oven too long.

*Why this matters to you—and more importantly your customer.* If you are a custom powder coater, you may already be aware of the information discussed in this article, but if you are an end user chances are you had no idea. The old saying "time is money" directly applies to the differentiation between powder and liquid coatings. In most cases, the cross-link cure mechanism of powder coating offers significant time savings to the end user. Although there are some industrial liquid coatings that cure rapidly through chemical reaction, many that I encounter in my marketplace take hours if not days to achieve final cure.

As a custom coater, you are also painfully aware that project schedules leave little time for the finishing, and we are often asked "how quickly can it be turned around?" Once our customers' goods have cooled, they are ready to be shipped and installed, or machined or assembled. The bottom line is our customers do not need to worry about waiting three days for full cure or marking a soft coating that has been rushed out or solvent entrapment from improper coating application. We get to be the good guys; we can get it done quicker, with a more durable product, and (I intentionally have not mentioned this until now) we are more environmentally sustainable due to our coatings being free of solvents and the VOCs that come with it.

## Now what?

In this article we have covered the following points:

- The unique cure mechanism of powder coating
- An introduction to how to properly cure on a straightforward product
- Tools the custom coater should have to verify and monitor cure
- The importance of the cure mechanism to our customers

Now we will look at how to effectively use the data logger and how to use it to balance your oven, and review two useful tests for evaluating full coating cure.

**Using a data logger.** Depending on the model of your thermal profile data logger, you will have as few as four probes and as many as the manufacturer may build into the device. The unit that we use has six probes. The first probe is always used as the air temperature probe. This is important as it should closely reflect the air temperature readout on your oven controller; if this is not the case, you may be in danger of under-curing or over-baking product if the difference between your readout and air probe is large enough.

The remaining probes should be used to measure part temperature. The size of the part and its configuration will dictate how you should apply the probes. Instead of running through different scenarios of how to apply the probes, following are some key questions to consider when applying probes:

- Does the part have varying density that may heat up at different rates?
- Does the part span enough length and height that it may be in different temperature zones in my oven?
- Does the design of the part leave some areas receiving more heat than others? (In one case, we had a piece that was oriented horizontally and then vertically. In each case, the airflow was different, resulting in a different thermal profile.)
- Is the probe secured well enough to survive the duration of the product in the oven? (There is nothing worse than pulling a test piece out to find a probe laying on the floor).

There are many benefits to using a data logger. In my mind, the most important benefit is being able to confirm through a quantifiable process that the customer's product has a properly cured finish on it. It also allows you to fine tune your process to save time and energy (read "money" in both cases) by having products in the oven for only as long as necessary. Furthermore, by creating a repeatable curing process for specific pieces, you are able to provide your customers with verifiable data that confirms they are getting what you have agreed to deliver.

**Balancing your oven.** There is a caveat, however. I mentioned that the first probe is to monitor air. If your oven temperature controller and your air probe read out differently (10°F difference or more), then you should take the time to troubleshoot your oven. If your thermal profiler is within specification having been calibrated with the manufacturers required time frame, then you will need to take a weekend to balance your oven.

Depending on the design of your oven, the steps taken to balance it will vary. However, to effectively gauge your oven, I recommend making a tree as in Figure 2 that will allow you to incrementally measure the temperatures.

The tree that we use breaks up our oven into six vertical zones. Furthermore, because our oven is a batch, we have four zones along the depth of our oven at which we take measurements. To move the tree along each zone, we have to open and close our oven door, which allows for heat loss. Taking this into consideration, we leave the tree in each zone for 15 minutes to allow the oven to reach the test temperature (425°F). Once the test is completed, the oven profiler software generates a report that we are then able to make our adjustments from. As seen in Figure 3[2], the first two zones are within an acceptable range; however, the third zone would benefit from some adjustment. The severe drops in temperature indicate the doors of the oven being open and closed.

The condition of your oven to begin with will determine the length of time it will take for you to balance it. The result you should be looking for is ±10°F from the target temperature throughout the oven.

**Verifying cure in other ways.** In case you do not have access to a thermal profile data logger, there are two low-tech tests you can conduct to assess whether full cure has been achieved on your thermosetting coating. The first test is the PCI #8 MEK Solvent Cure Test and the second is the ASTM[3] D3359 Standard Test

FIGURE 2

Balancing an oven with a temperature profiler

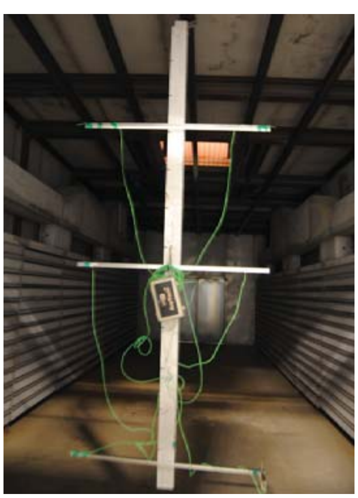
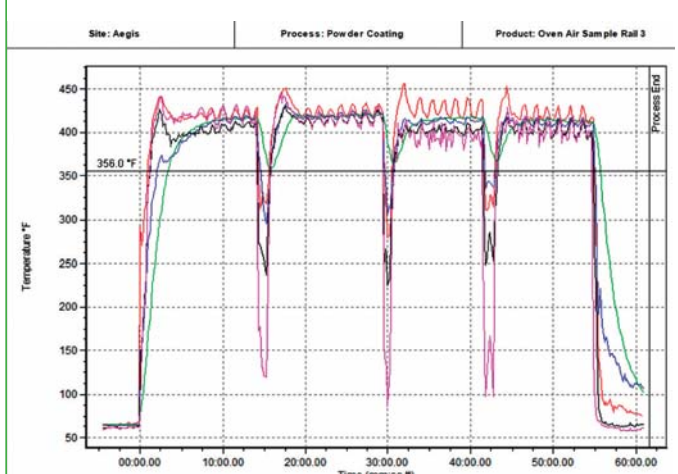


FIGURE 3

Oven profiler software report



Methods for Measuring Adhesion by Tape Test, more commonly known as the crosshatch adhesion test.

(Note: When conducting these tests, please be sure to comply with all applicable safety requirements for your jurisdiction.)

*MEK solvent cure test.* The first test I recommend is the MEK (methyl ethyl ketone) solvent cure test. The outline for how to conduct this test can be obtained from the Powder Coating Institute (PCI) at www.powdercoating.org. When properly conducted, this test will determine—subject to interpretation—the degree of cure of the sample plate. This **is** a destructive test, so if it is to be conducted on a customers finished product, it is best to perform it in an inconspicuous area.

In Table 1 and Figure 4, three sample plates have been subjected to the MEK test and the crosshatch adhesion test. After 100 double rubs with the MEK-soaked cloth, the coating on Plate B softened to the point where the coating wore through to the primer coat below. (See Figure 5). This indicates that the powder coating did not cross-link. Compare this with the cloth shown in Figure 6, which shows little to no color transfer after 100 double rubs on Plate A.

*Crosshatch adhesion test.* The second test that can be conducted with ease is ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test. While the proper tool kit and ASTM standard should be purchased and used to ensure the test is conducted according to a repeatable procedure, when done for internal verification, a sharp knife and duct tape can suffice. By cutting a crosshatch pattern on the sample plate and firmly applying the duct tape, remove the tape backwards and observe what, if any, coating is on the adhesive surface. Again, looking at Figure 4, sample Plate C has failed the crosshatch adhesion test, yet it passed the MEK test. This is an indication of the coating being over-cured and not properly adhering to the basecoat beneath.

## Conclusion

Every oven is built differently. This being the case, the cure times that you may determine for your customers' products do not necessarily translate to how the product should be cured in a different oven. A properly applied coating does not happen by chance; it is the result of deliberate steps being taken to ensure repeatable and verifiable results. As with many things, there is some art to applying powder coating. As discussed in this article, however, there are many quantifiable ways that we can ensure the coating is properly cured and therefore capable of providing the performance as intended by the coating manufacturer. **PC**

**Table 1**

**Testing degree of cure**

| | MEK test | Crosshatch adhesion | Degree of cure |
|---|---|---|---|
| A | Pass | Pass | Full |
| B | Fail | Pass | Under |
| C | Pass | Fail | Over |

**Figure 4**

**Testing degree of cure on three panels**

(A) (B) (C)

**Figure 5**

**MEK testing on plate B showing degree of cure**

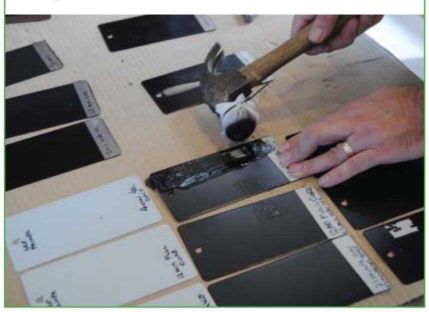
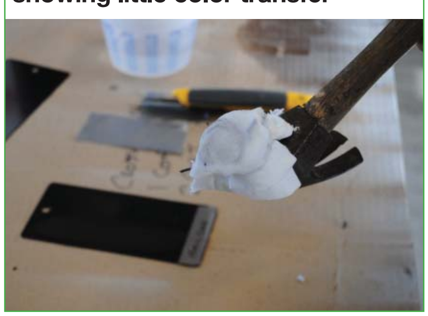


**Figure 6**

**Testing degree of cure on plate A showing little color transfer**



## Endnotes

1. TIGER Drylac; see www.tiger-coatings.com.
2. Datapaq; see www.datapaq.com.
3. American Society for Testing and Materials; see www.astm.org.

## Editor's note

For further reading, see *Powder Coating* magazine's website at www.pcoating.com. Click on Article Index and search by subject category. To submit a question, click on Problem Solving, then scroll to Coater's Corner.

*Chris McKinnon owns Aegis Industrial Finishing Ltd. with his father in Surrey, BC. As a third generation metal finisher (his grandfather started a plating company in 1948, and his father has worked in powder coating for more than 20 years), he is actively developing new markets for powder coating and providing those who will listen a greater appreciation for powder coating. He has an MA in Business Leadership and holds his NACE CIP Level 1. His company is focused on providing powder coating and sandblasting to the local market and specializes in process-driven quality. If you would like to contact Chris, he can be reached at chris@aegisfinishing.com.*

*This column discusses problems encountered by powder coaters during the daily operation of their powder coating lines. These are in-the-field experiences from coaters. Its intent is to provide practical information to line personnel who coat all day to help them improve in their work. If you would like to contribute to this column, contact Peggy Koop, editor, at 651/287-5603, or e-mail pkoop@cscpub.com.*