

## 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 W.E. (Bill) Pasley, Southern Company, Atlanta, Ga.; telephone 404/506-4017; e-mail [wepasley@southernco.com].*

# New changes to NFPA standard help reduce your oven heating requirements

Every 3 years the National Fire Protection Association (NFPA) initiates a cycle of review for various standards. During this cycle, parties may submit requests to make changes to the standards. A very formal process assures that such requests are proper and are in the best interest of safety.

The most recent cycle for the NFPA 86 standard, which deals with ovens and furnaces (more specifically: "Class A, Class B, Class C, and Class D ovens, dryers, and furnaces, thermal oxidizers, and any other heated enclosure used for processing of materials and related equipment"), has just been completed. The current edition, which is known as the 2007 edition, will be updated and published as the 2011 edition. The final acceptance of the various change requests occurred at the NFPA annual meeting in June of this year.

The reader may learn the many detail changes to NFPA 86 by attending the IHEA Safety Standards seminar Oct. 18-19 in Chicago. For more details, see [<http://iheaa.org/SafetySeminar.cfm>].

### Formulary versus actual

The area of the standard that has changed and that will allow for reduced energy usage is in the section that specifies the "Method for Calculating Ventilation Rate for Powder."

Reference is made to page 32 of the "Report on Comments A2010." This publicly available document can be accessed at [<http://www.nfpa.org/assets/Files/PDF/ROP/86-A2010-ROC.pdf>].

The statement within the document that allows for this change says the following:

**"Recommendation:** Revise text to read as follows: ~~10.1.6.4~~\*10.1.5.3\* Method for Calculating Ventilation Rate for Powder Curing Ovens. The method for calculating the minimum ventilation rate for powder curing ovens shall be as follows: (1) The safety ventilation required for powder curing ovens shall be based upon the percent of volatile content of the powder (R) released during the oven cure cycle. If a percentage is not available, the safety ventilation shall be calculated by assuming that 9 percent of the mass of the powder is xylene volatile and the remaining mass is inert."

The bottom line is that the exhaust calculations could be based on the *actual* material safety data sheet (MSDS) volatile organic compound (VOC) content of the powder being used. Historically, there was a formula that stated that the VOC calculation must be based on an equivalent of 9 percent of the powder weight in xylene solvent. The author is not aware of the thought process

behind this. Perhaps there were too many unknowns in the early years of powder coatings and, as stated in the referenced report, "...xylene provides an additional safety factor as xylene has one of the highest ventilation rate requirements of commonly used solvents in paint coating and curing processes."

**Traditional oven exhaust requirements.** Traditionally, an oven is designed to cure a particular coating, or set of coatings, and the exhaust of the oven is based on two components. The first component is the "product of combustion," if the oven is direct fossil-fired, and the second component is the amount of VOCs that are emitted within the oven during the drying/curing process. The two calculated exhaust cubic feet per minute (cfm) requirements are then added together to determine the total exhaust requirements for the oven.

### Actual VOC content of powders.

So how much difference might one expect by using the actual VOC content of the powder versus the xylene method? As part of the author's investigation into this, several powder manufacturers were contacted. One company responded with the following statement (mid-2009):

"For any powder except urethanes using blocked isocyanates, the vola-

tile factor should be something less than 1%, on the order of 0.3% based on some work done with functional coatings in [the] last month or so. For urethanes, the range can be from 0.3% (internally blocked NCO) up to almost 5% for matte coatings. I would think that the tendency would be that most of the urethane usage would be in reduced gloss situations so a factor leaning to this would be advisable, say something like 3%.... And actually, the high limit on the Matte urethanes is 7.6% ...There are some experimental resins that we have recently formulated with up to 10.4%.”

A perusal of some Web sites provides some insight. For example, Rohm and Haas’ site states:

“Under typical curing conditions, glycouril cured polyesters (and epoxies) release methanol at levels up to 1.5%.” Reference: [http://www.rohmhaaspowdercoatings.com/pc/ps/technical\_briefs/techbriefs\_vocs.page].

All of the previous information points to the fact that the end user of the powder will have to rely on the MSDS to provide the specific VOC content for the powder being used.

**Basic Btu energy calculations.** The amount of energy contained in exhaust air can be calculated as follows:

$Btu = (\text{flow rate}) \times (\text{time}) \times (\text{density of air}) \times (\text{specific heat of air}) \times (\text{degrees F}).$

Using standard condition numbers, this becomes:

$(\text{cfm}) \times (1 \text{ hour}) \times (60 \text{ min/hour}) \times (0.075 \text{ pound/cubic foot of air}) \times (0.24 \text{ Btu/pound degree F}) \times (\text{delta T in degrees F}).$

This simplifies to:

$Btu \text{ per hour} = 1.08 \times \text{cfm} \times \text{delta T in degrees F}$

Remember to make sure that you use standard cubic feet per minute (scfm); you can adjust cfm to scfm by multiplying cfm by the ratio of  $(T + 460)/(70 + 460)$  where T is in degrees F.

**Example calculations.** The 2007 NFPA 86 Standard contains an appendix wherein an example calculation is shown for calculating the total exhaust requirement for a powder curing oven. A hypothetical oven is used with a 2,000,000 Btu burner. The operating temperature is 450°F, the elevation is 1,000 feet, and 7,000 square feet per hour is being coated with 3 mils. The reader is referred to the standard for more details (reference Annex material A.10.1.6.4).

The salient point is that the calculations are using the 9 percent xylene

equivalent VOCs. With this number, the exhaust calculated for VOC removal plus combustion products is 814 cfm at 70°F. Corrected for operating temperature and 1,000 feet of elevation, this becomes 1,398 cfm.

If a VOC content of 3 percent were used instead of the 9 percent and the VOC were xylene, then the exhaust requirements calculated for VOC removal plus combustion products are reduced by 533 cfm at operating temperature and 1,000 elevation. If the VOC content is 1 percent, then the reduction is 711 cfm.

*Calculating your savings.* Your savings will depend on the operating parameters of your oven and the specifics of coating thickness, square footage, etc. The procedure described previously can show you the difference in Btu per hour (Btuh) you can expect by using the MSDS VOC numbers versus the old xylene requirement. Applying the annual operating hours and your cost per million Btu for fuel will give the annual dollars saved. (See Figure 1.)

At \$5 per million Btu (MMBtu), 1 percent xylene, and 2,500 hours per year, the example calculation yields an annual savings of \$3,648. At \$10/MMBtu, the savings jump to \$7,296 per year. This does not include any electricity cost savings as a result of reduced exhaust fan energy usage.

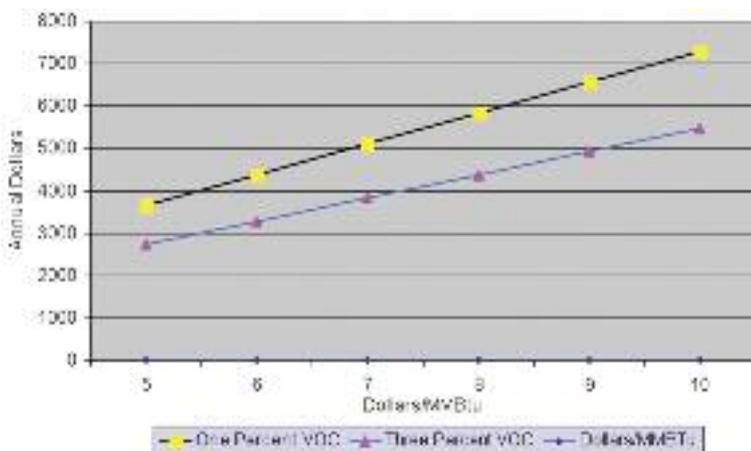
Note that your powder VOC emissions may be something other than xylene. See the sidebar with this column for a discussion and table of expected VOC content for various powders. **PC**

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**FIGURE 1**

**Energy savings versus fuel price for 1 percent and 3 percent VOC (xylene equivalent) powder content versus 9 percent xylene using NFPA Annex Sample Calculation**



Note: Each facility energy savings would be different based on facility-specific parameters. See article for parameters in this example.

For more information or to submit a question, contact Anne Goyer, executive director of IRED, at 859/356-1575; e-mail [aygoyer@one.net]. See also [www.IHEA.org]. Click on the IRED link.

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## Health, safety, and environmental information: Volatiles in powder coating

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Whenever a thermoset coating powder is applied and baked within a temperature range of above 212°F (100°C) to a maximum of 500°F (260°C), a weight loss of the applied powder due to the emission of volatile compounds occurs. This technical brief describes the chemical nature of these chemical compounds. The data ranges for volatile

compounds given in this brief are typical for 95-98 percent of all commercially used thermoset decorative powder coatings.

**Formula added volatile compounds.** The most easily traceable volatile components in powder coatings are those added by design into formulas, or those being a known part of raw materials used in these formulas. Moisture (water) absorbed in raw materials coating powders, including moisture absorbed by finished coating powders, can account

for up to 1 percent of volatile compounds liberated through the bake cycle. The most commonly used degassing additive, benzoin may add another 0.2-1 percent to our mixture of volatile compounds.

Another big group of volatile contributors includes blocking agents used in isocyanate curatives for polyurethane powders. E-caprolactam (or E-cap for short) is the most commonly used blocking agent for isocyanates. Lower temperature (around 300°F, or 150°C) curable

TABLE 1

### The most common powder coating chemistries, their cure mechanisms, and the types of volatile compounds emitted

Powder coating type	Curing (cross-linking) mechanism	Volatiles (% range)	Reaction by-products, volatiles emitted
Epoxy	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, organic anhydrides (rarely), traces of other compounds <sup>a</sup> .
Carboxylated polyester/epoxy hybrid	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, E-cap (sometimes), traces of other compounds <sup>a</sup> .
Carboxylated acrylic/epoxy hybrid	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, traces of other compounds <sup>a</sup> .
Hydroxylated polyester/blocked isocyanate (emissive polyurethane)	Addition	3-10	Blocking agents (E-cap, triazole) can be considered reaction by-products. Other typical volatiles: Water, benzoin, traces of other compounds <sup>a</sup> .
Hydroxylated polyester/uretdione (non-emissive polyurethane)	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, traces of other compounds <sup>a</sup> .
Carboxylated polyester/triglycidyl isocyanurate (TGIC)	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, E-cap (sometimes), traces of other compounds <sup>a</sup> .
Carboxylated polyester/glycidyl methacrylate (GMA) acrylic	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, traces of other compounds <sup>a</sup> .
Carboxylated polyester/hydroxy alkylamide (HAA) (Primid Systems)	Condensation	2-4	Reaction by-product: Water. Other typical volatiles: Water (moisture), benzoin, traces of other compounds <sup>a</sup> .
Hydroxylated polyester/glycoluril (Powderlink Systems)	Condensation	3-6	Reaction by-product: Methanol. Other typical volatiles: Water, benzoin, formaldehyde, traces of other compounds <sup>a</sup> .
GMA acrylic/diacid	Addition	0.5-3	No reaction by-products. Other typical volatiles: Water, benzoin, traces of other compounds <sup>a</sup> .
Other (polysiloxane systems, 'cocktail' systems)	Addition and/or condensation	1-8	Possible reaction by-products: Water, methanol. Other possible volatiles: Water (moisture), benzoin, blocking agents (E-cap, triazole), formaldehyde, organic anhydrides (rarely), and traces of other compounds <sup>a</sup> .
Ultraviolet-curable epoxy or polyester	Cationic or free radical cure	<2	No reaction by-products. Other typical volatiles: Water, traces of other compounds <sup>a</sup> .

Note: <sup>a</sup>Traces of other volatile compounds could include those mentioned in the sidebar under the heading "Volatile compounds contained in raw materials."

polyurethane powder coatings may contain triazole as a blocking agent. The percentage of blocking agents emitted during the bake cycle of polyurethane powder coatings can range from as low as 2 percent to as high as 10 percent for some specialty products. Certain additives used in powder coating formulas may contain some volatile organic compounds (VOCs), such as aliphatic and aromatic hydrocarbon based solvents, esters, and ketones, among others. The amount of these volatile products is typically limited to less than 0.5 percent for any given coating powder, and the majority of all formulas contains no, or only trace amounts, of these volatile chemicals.

**Volatile compounds generated from the thermoset cure reaction.** Chemical condensation reactions occurring during the cure (bake) cycle contribute to the emission of volatile compounds. Here again, water is a common by-product of condensation reactions occurring in some powder coatings, accounting for up to about 1 percent in some chemistries. Methanol and formaldehyde (up to 3 percent for the first, up to 600 parts per million [ppm] for the latter) are condensation by-products of another type of powder coatings.

**Volatile compounds contained in raw materials.** Powder coating resins and curatives may contain trace amounts of monomers used to produce them. Glycols, organic acids, acrylic monomers, bisphenol A, epichlorohydrin, and amino compounds

make up for less than 50 ppm, and often less than 5-10 ppm, of organic volatiles emitted. One exception is some classes of organic anhydride curatives used occasionally in functional and decorative epoxy powder coatings. They have a tendency to sublime at higher bake temperatures, generating amounts of up to 1 percent of volatilized anhydrides. Additives, such as flow agents, waxes, and other degassing and leveling compounds, contain trace amounts of acrylic monomers, hydrocarbons, silanes, siloxanes, and other by-products that can volatilize under higher bake temperature conditions, especially above 392°F (200°C).

Again, the amount of organic volatiles is typically less than 100 ppm, and often below 10 ppm. Diarylide pigments can decompose at temperatures above 392°F (200°C), generating larger amounts of volatile aromatic amines. Pigment manufacturers have issued special warnings regarding the temperature sensitivity of diarylide pigments. Most inert components of coating powders, such as pigments and fillers, contain mostly moisture and only trace amounts of organic volatile compounds.

The most common powder coating chemistries, their cure mechanisms, and the types of volatile compounds emitted, are listed in Table 1.

**Special note.** Longer term exposure of any coating powder, or any powder coating film, to temperatures above 482°F (250°C) will lead

to thermal decomposition and/or oxidation (in the presence of air) of organic compounds, resulting in a multitude of volatile chemicals generated and emitted. We recommend consulting the material safety data sheet (MSDS) for powder coating products whenever such extreme conditions occur.

PC

## References

C. Danick, "Weight Loss Which Occurs During the Curing Process of Powder Coatings," Powder Coating '94 (October 1994), conference proceedings.

N.P. Liberto, Ed., *Powder Coating—The Complete Finisher's Handbook*, Second Edition (Alexandria, Va.: The Powder Coating Institute, 1999).

Information and data listed in technical literature from raw materials manufacturers and suppliers.

Information and data verbally submitted by raw material manufacturers and suppliers.

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