Drying and Curing Waterborne Industrial Coatings

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Market Overview

Coatings in the industry consist of compounds containing water, solvent and solids as base components. Manufacturers are currently moving away from solventborne coating that increasingly no longer meet strict environmental regulations. Solventborne coatings continue to maintain a large portion of the market despite their long term decline in popularity for compliant coatings.

Compliant coatings such as waterborne, powder, and radiation curables have made a distinct impression on the market. These compliant coatings address the issues of VOC emissions, efficiency in coating application, and reduction in waste material.

The overall industrial paint and coating market is expected to expand at a rate of 2.5% to 1.3 billion gallons of paint per year by the year 2002, valued at $17 billion according to a study from the Freedonia Group Inc. Even more importantly there will be a major change in the types of coatings used in the industrial segment. Low solids solventborne coatings will continue to be replaced by low or non-solventborne coatings. In 1999, formulators report their companies anticipate spending 54% of their coating R&D budget on waterborne research. The sales of waterborne, powder and radiation curable coatings are projected to increase by 5% a year, and by 2002 waterborne coatings will achieve 30% of the market and show a 45% increase from 1993.

With respect to the increased sales of compliant coatings, finishers spending patterns are also effected. Although most equipment can be reused or retrofitted to maintain production with waterborne coatings, new finishing equipment purchased by manufacturers has increased substantially. Manufacturers surveyed indicated the major reasons for spending were environmental compliance and improved productivity.

Systems

Traditional methods for drying and curing waterborne coatings with ovens and radiation systems have remained the same. The development of new technology such as dehumidification address many concerns in the use of waterborne coatings. A brief description of each is as follows:

Convection Ovens:

Convection ovens have been widely used for the drying and curing of coatings and dry-after wash of parts. The basic operation of a convection oven is to generate a high enough temperature, combined with air movement over the coated parts to evaporate the water by raising its latent heat. As the water is evaporated, the recirculated air absorbs it, thus increasing its relative humidity. In order to remove this moisture from the oven enclosure, a large volume of recirculated air must be exhausted and fresh air must be introduced. This dilution method of moisture removal is not energy efficient since all of the make-up air must be heated to temperature and the heated exhaust air is wasted. In addition, the actual diluted air in the oven will vary from winter to summer seasons due to the changes in ambient air conditions.

Since the product is heated, a cooling tunnel or extended ambient cool down area is typically needed. This means additional line space, capital cost and operating costs.

Infrared Ovens:

Infrared ovens operate with radiation that directly transfers the heat very rapidly to the coating. The coating is heated from the inside out with substrate absorbing very little energy. However, IR ovens are limited by line of sight, meaning complex shapes are difficult to dry. In addition, the water that is evaporated must be removed by means of dilution just as the convection oven. The same problems remain.

Dehumidification System

The process of drying waterborne coatings and dry after wash applications with low relative humidity air at ambient temperature meets the majority of concerns associated with these applications. This system operates by recirculating the moisture laden air through a series of filters where particulate, VOC's and HAPS are removed. The air is then directed through an industrial dehumidification system where the moisture is removed. The clean, dry air is then circulated back into the enclosure and across the parts where the cycle is repeated. Further details of this process will be explained later. Controlling the relative humidity in the enclosure eliminates weather sensitive production cycles and maintains a uniform process control throughout the year.

The exhaust system can be substantially reduced or eliminated altogether because the water is removed by means of condensation and not by dilution. This results in a lower operating cost of approximately one-tenth of a convection oven. Also, since the parts are dried at ambient temperature, the cooling tunnel or cooling loop can be eliminated.

Chemistry of Drying Waterborne Coatings

In order to understand the different methods of drying waterborne coatings, it is necessary to review the chemistry on how the water is removed from the coating itself. Typical waterborne paints are composed of 50% water, 45% solids and 5% co-solvents. The water and co-solvents are removed from the surface of the paint coating via evaporation. The water below the surface migrates to the surface at a speed based upon the rate of diffusion of the coating. This process continues until all of the water has risen to the surface and is evaporated.

The time in which the water is evaporated and the coating is dry is based upon the amount of water to be removed (i.e. thickness of coating and % water in the paint) and the evaporation rate. For a typical waterborne coating applied at three (3) mil wet, a dehumidification system will dry the coating and be able to pack it in a range of three (3) to eight (8) minutes without adding any heat.

The evaporation rate is dependent upon the vapor pressure difference between the water in the coating and the air being circulated over the surface of the part. The vapor pressure difference is a function of the humidity ratio (i.e. temperature and relative humidity of the circulating air) and to a smaller degree, the velocity of the air across the substrate.

Driving Force

If the velocity is held constant, then the difference in vapor pressure attributed to the temperature and relative humidity is called the "*Driving Force.*" This is expressed mathematically as:

Driving Force = $HR_{@\text{Sat \& Twb}} - HR_{@\text{Tdb \& RH}}$

where:

$HR_{@\text{Sat \& Twb}}$ = Humidity Ratio at the saturation point along the wet bulb temperature of the circulating air.

$HR_{@\text{Tdb \& RH}}$ = Humidity Ratio at circulating air dry bulb temperature and relative humidity point.

In order for the process to be energy efficient, it is important to recognize how much energy is required and at what rate to evaporate the water.

A low temperature oven of 130?F to 180?F impinges the coating with a driving force of about 0.009 and 0.020, respectfully. While this drives the water out of the coating, it does it too quickly. This causes the water to boil and creates such defects as pops or pin-holing. A dehumidification system operating at 85?F and 30% RH has a driving force of 0.005. While this is less than the oven, it allows for a more controlled removal of the water from the coating that allows the water to evaporate without boiling and causes fewer defects. It is also more energy efficient.

Information Required for Sizing a Dehumidification System

The main difference in sizing a dehumidification system compared to that of an oven is that mass of the product does not matter. Only the amount of painted surface area and thickness of the coating is important. This means that a thin sheet metal part that has the same surface area as that of a heavy casting would require the same size system.

The information required to size a dehumidification system is:

- Sq.Ft. per hour of painted surface area.
- % Solids by volume of the coating.
- % Water by volume of the coating.
- Wet mils of paint applied to the substrate.
- Dry mils of coating required on the substrate.

OR

- Max. paint usage (gal./hr.)
- % Transfer efficiency of application equipment
- % Water by volume of the coating

The moisture removal rate (MRR) can be calculated by the following formula:

$$\text{MRR (lb./hr)} = \text{Surface Area/Hr} \times \text{Wet Mil} \times \text{\% Water} \times 0.005171$$

An alternative method of calculating the MRR is:

MRR (lb./hr) = Paint Usage (gal/hr) x % T.E. x % Water x 8.3 lb./gal water

Energy Cost Savings

The following is an example of the energy savings of a Dehumidification System compared to a convection oven. The same format can be used for various examples by substituting for different usage values and energy rates.

	Gas Oven & Cooling Tunnel	**Dehumidification System**
Electric		
Production Hours per year	2000	2000
Load (KW)	33	17
Total Usage (KWH)	66,000	34,000
Rate per KWH	$ 0.06 / kwh	$ 0.06 / kwh
Electrical Cost per Year	$3,960 /yr	$2,040 /yr
Natural Gas		
Production Hours per year	2000	2000
Load (BTU)	2,000,000	no usage
Total Usage (MMBTUH)	4,000	0
Total Usage (Therms)	40,000	0
Rate per Therm	$ 0.50 / therm	$ 0.50 / therm
Electrical Cost per Year	$20,000 /yr	$0 /yr
Total Energy Usage per year	$23,960 /yr	$2,040 /yr
Annual Savings per year	$ 21,920 /yr	

Typical Applications for Dehumidification

A dehumidification drying system can be used in several areas of a paint shop. Some examples are:

- Dry after Wash prior to Waterborne painting
- Dry after Wash prior to Powder Coating
- Waterborne Primer Dryer
- Waterborne Topcoat Dryer
- Flash-off between Waterborne Basecoat and Solvent Clearcoat
- Waterborne Adhesive Dryer
- Drying of Waterborne UV/EB Coatings

Advantages of Dehumidification System

There are numerous advantages to a dehumidification system over a convection oven or IR oven when drying waterborne coatings. The major advantages are:

- No flash-off time required between the spray booth and the drying enclosure. This can save on floor space and eliminate additional enclosures.
- Improves the quality of the paint finish. There is less pin-holing and other defects than convection or IR oven due to no heat being added to the process.
- Heat sensitive parts such as plastic, rubber, or wood are not deformed or damaged because the system is operated at ambient temperatures.

? No heat ramp up times for heavy parts such as castings or frames. This reduces the overall drying time of the process. The dehumidification system is not effected by the mass of the product.

? No cooling tunnel or cooling loop required. Reduces the footprint required for the paint system and saves capital and energy operating costs.

? A dehumidification system is very energy efficient. It operates at approximately one-tenth the energy cost of convection or IR oven.

? The drying process is controlled throughout the year and the drying time remains the same. There are no production upsets during the humid summer.