The Basics of Dehumidification

Dehumidification, or removing moisture from the air, is one method to control the environment when blasting and painting. It helps prevent flash rusting and promotes the curing of coatings. This Applicator Training Bulletin will discuss the basics of moisture, starting with an explanation of moisture in the air and its relationship to corrosion. After an explanation of humidity, the various types of dehumidification will then be presented along with the basics of sizing dehumidification needs. The uses and benefits of dehumidification will then be highlighted.

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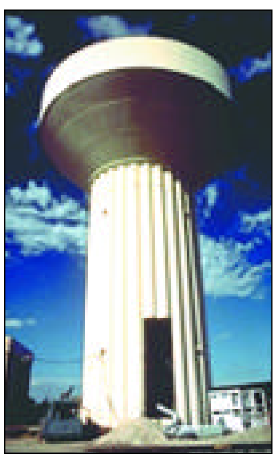
Corrosion and Humidity

Good painting practice requires the surface of the steel to be 3 degrees C (5 degrees F) or higher than the dew point to prevent moisture from condensing on the surface. Moisture condensing on a blast-cleaned steel surface will cause rust and can interfere with adhesion of the primer. Moisture condensing on a newly coated surface can affect the cure of the coating.



Water towers can be dehumidified through the bottom of the tower. Photos courtesy of Enviro-Air Corporation

An important concept is dew point temperature. This is the temperature at which moisture will condense on the surface. At the dew point temperature, the air immediately next to the surface is at 100% relative humidity. Moisture cannot evaporate from the surface when the air next to it is at 100% relative humidity. In fact, the opposite happens. Moisture in the air actually condenses on the surface.

It is important to understand why good painting practice requires a separation of at least 3 degrees C (5 degrees F) between surface temperature and dew point temperature. There are three reasons. One is the inherent accuracy of surface temperature and dew point measurement instruments. The second is that solvent evaporation from the curing of paints is a cooling process. So the 3-degree C (5-degree F) difference provides a margin of safety to make sure moisture is not condensing on the surface. The third reason is to account for the change in temperature or relative humidity after work has begun.

Absolute and Relative Humidity

Most people are familiar with relative humidity because that is what gets reported with the weather forecast. One of the reasons it is important to people is that it is an indicator of comfort. The reason people sweat is to control body temperature. As we sweat, the water (solvent) evaporates, which is a cooling process. The higher the relative humidity, the less evaporation takes place so our bodies are not cooled as much. When the temperature is high, say 32 C (90 F), we are more uncomfortable at 90% relative humidity than at 40% relative humidity.

Air is a mixture of gases, mainly nitrogen and oxygen. It also contains water (moisture). The absolute humidity is the amount of water in a unit volume of air, usually expressed in grams per cubic meter. The hotter the air is, the more water it can contain. Relative humidity is the amount of moisture in the air (absolute humidity) compared with the maximum amount of moisture that the air can hold at the same temperature. Since warm air can hold more water than cool air, there is less water in 20 C (68 F) air compared to 25 C (77 F) when they are both at 50% relative humidity.

If we take the air at 25 C (77 F) at 70% relative humidity, it would have to be cooled to 18 C (64 F) to reach 100% relative humidity, i.e., the dew point. At 25 C (77 F), if the relative humidity is 50%, the air would have to be cooled to 13 C (55 F) to achieve 100% relative humidity. What this says is that the dew point temperature is lower when the relative humidity is lower for air at the same temperature (Table 1).

Controlling Ambient Conditions

There are two recognised methods for artificially maintaining conditions so that moisture does not condense

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on the surface. One is to heat the steel being painted so that the surface temperature stays at least 3 degrees C (5 degrees F) above the dew point. This would be practical for small work pieces where radiant heaters could be used. But it is usually too costly to do for large surfaces such as the inside of a storage tank. The second recognised method would be to use dehumidification. There is a third method, which is to heat the air. Heating the air will lower the relative humidity since warm air can hold more water than cool air. But heating does not change the absolute amount of water in the air. Water will still condense on the steel surface if the temperature of the steel is not increased, also. Heating steel with warm air is inefficient due to the poor heat transfer between air and steel and the steel's large heat capacity. Heating the air does not change the dew point, but it does make it more likely that the steel temperature will remain at 3 degrees C (5 degrees F) above the dew point.

Table 1:
Relationship among Temperature, Relative Humidity, and Dew Point

	Initial Temp C (F)	Initial RH (%)	Final Temp C (F)	Final RH (%)	Dew Point C (F)
Case 1	25 (77)	70	18 (64)	100	18 (64)
Case 2	25 (77)	50	13 (55)	100	13 (55)

The rate of atmospheric corrosion of steel is determined by three factors: steel temperature, the presence of pollutants, and relative humidity. Steel temperature affects how fast the corrosion reactions occur in a similar manner to most chemical reactions; namely, they go faster at higher temperatures. Pollutants, either in the air or on the surface, make condensed water more conductive. Corrosion occurs faster with conductive water. Relative humidity has also been found to affect the rate of corrosion. The rate of the corrosion reaction increases exponentially with relative humidity. For uncontaminated steel, the rate of corrosion is essentially zero below 60% relative humidity. Most people use 50% relative humidity as the point of "no corrosion" because it provides a margin of safety (and is easier to remember). Salt-contaminated steel may still corrode at 30% relative humidity because salt is hygroscopic and removes moisture from the air. Salt also produces the tendency for moisture to condense.

The major purpose of dehumidification is to reduce the amount of moisture in the air, lower the dew point temperature, prevent moisture from condensing on the steel, and reduce the rate of corrosion.

Paint Curing and Humidity

Dehumidification can also aid in the curing of paints. It controls moisture condensation in the coating film and speeds up the release of solvents. Solvent evaporation is a cooling process. So the surface temperature can fall as the solvents are released. Water condensation can occur if the surface temperature is near the dew point temperature.

The other concern is solvent entrapment in the film if the solvents do not evaporate. Air can hold only a given amount of solvent at a specific temperature. Water is a solvent. So if the relative humidity is high, there is little room in the air for solvent. Lower relative humidity allows more solvent to evaporate into the air.

Dehumidification Equipment

There are four types of dehumidification.

• Condensation-Based (refrigerant): This method relies on passing the air over evaporator coils to reduce the absolute amount of the humidity in the air. A cold liquid circulates in the evaporator coils. The air being treated is cooled, causing the moisture to condense on the cold surface of the coils. The air is then passed over a series of reheat coils, an action that raises the temperature, thus reducing the relative humidity.

• Solid Sorption (desiccant): This method utilises a chemical to directly absorb moisture from the air. This chemical can be either in granular beds or on porous structures such as on filters or rotating wheels. The air is passed through the desiccant material, where the moisture is removed from the air. Eventually, the desiccant will become saturated and won't be able to remove any more water. The desiccant is reactivated by reversing the reaction, i.e., passing heated air through the desiccant to de-sorb the attached water. Common desiccants are silica gel, lithium chloride, and zeolites (hydrated aluminosilicate minerals).

• Liquid Sorption: This method is similar to solid sorption except that now the air is passed through sprays of a liquid sorbent. The sorbent must be continually regenerated by using heat to drive off the absorbed moisture. Lithium chloride or glycol solutions are examples of liquid sorbents.

• Compression of the Air: This is similar to the operation of an air compressor. The air is compressed, which causes moisture to condense. The moisture is then removed with water traps and after coolers. Re-expansion of the air

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then results in a lower absolute humidity.

Only condensation-based (refrigerant) and solid sorption (desiccant) dehumidification equipment are practical for industrial painting projects. As a general rule, refrigerant dehumidifiers are usually preferred when the outside air temperature is relatively warm. They have lower power requirements so they are cheaper to run. But when the air temperature is cool and the dew point is below 0 C (32 F), the equipment will ice up. Desiccant driers are often preferred at lower temperatures. Desiccant driers maintain their efficiency at removing water from the air at all temperatures, while refrigerant driers become less efficient at cooler temperatures (though reheat air can be used to overcome this situation).

Sizing Dehumidification Equipment

The most common method for sizing dehumidification unit needs for a project is the air exchange method. The number of air exchanges needed per hour is selected, and the size of the equipment is based on the volume of the space being dehumidified. Typically, four air exchanges are recommended.

Dehumidification equipment comes sized in the volume of air it can deliver, i.e., cubic meters per minute (CMM) (cubic feet per minute [CFM]). The size of the equipment needed can be calculated from the following equation:

$$\text{CMM (CFM)} = \text{Volume of enclosure} \times \text{air exchanges} \times \tfrac{1}{60}$$

The $\tfrac{1}{60}$ converts air exchanges per hour to air exchanges per minute.

Suppose the project is painting the interior of a tank that is 27 m (90 ft) in diameter and 12 m (40 ft) high. The first step is determining the volume of the tank, which is:

$$\begin{aligned}\text{Volume} &= \pi \text{ (i.e., 3.14)} \times \text{radius}^2 \times \text{height, or}\\ &= 3.14 \times 13.5\text{ m}^2 \times 12\text{ m } (3.14 \times 45\text{ ft}^2 \times 40\text{ ft})\\ &= 6{,}870\text{ m}^3\ (254{,}000\text{ ft}^3)\end{aligned}$$

The size of the dehumidification unit needed based on four air exchanges per hour would be:

$$\begin{aligned}\text{CMM (CFM)} &= 6{,}870\text{ m}^3 \times 4 \times 1/60\ (254{,}000\text{ ft}^3 \times 4 \times \tfrac{1}{60})\\ &= 460\text{ CMM } (17{,}000\text{ CFM})\end{aligned}$$

There is another method for sizing dehumidification systems that is based on the temperature and relative humidity differences between daytime and nighttime. The absolute humidity, or amount of water, that must be removed can be calculated. The efficiency of the dehumidification equipment at removing water from a unit volume of air will then determine the actual size needed. The calculations in this method are quite complex and beyond the scope of this article. To learn about this method, the reader is referred to an article by D. Bechtol, "Dehumidification in Blast Cleaning Operations," (JPCL, July 1988), pp. 32–39.

Having the right size dehumidification unit does not guarantee success for the project. The air must move across the surfaces to be effective. The air escapes should be on walls opposite the dehumidified air intake. Multiple inlet ducts may be needed to distribute the air. When using dehumidification for removing solvents from coatings, remember that solvents are heavier than air, so they will settle to the bottom of the tank. The air flow should be concentrated on the floor.

Dehumidification equipment set up for painting operations inside three tanks.

Uses and Benefits of Dehumidification

Dehumidification has a number of uses in the construction industry that relate to painting activities. Dehumidification equipment can be used to dry concrete. In the December 2001 Applicator Training Bulletin on floor coatings, it was stated that the maximum moisture emission rate most commonly required by manufacturers of floor toppings is 15g/m2/24 hours (3.0 lb/1,000 ft2/24 hours). If the concrete has cured for the minimum of 28 days normally recommended and has met specified strength requirements, all that is needed is to lower the free moisture content to achieve the desired emission rate. Dehumidification equipment can speed up the process.

Surface preparation by power washing or waterjetting can require waiting a day or two while the surface completely dries, especially when there are crevices present between steel members. Dehumidification after power washing or waterjetting can remove this water more quickly.

The main benefit of dehumidification is the ability to control the work environment. This can be economical for a contractor and result in a better coating application.

Contractors benefit from dehumidification equipment by reducing downtime. There is no need to wait when ambient conditions are out of specification because the environment inside the work area is controlled. Productive work can begin first thing in the morning, especially in the spring and fall when dew normally forms. It also eliminates days lost due to rain. Maintaining the relative humidity below 50%, or the surface temperature 6 degrees C (10 degrees F) above the dew point will control rust bloom on a blast-cleaned steel surface for a week or two. This allows the contractor to blast clean the entire surface (or large portions of the surface) continuously without the daily stop for clean-up and priming. Putting on the primer in one application prevents blasting particles from landing on the surface primed the previous day and allows the primer to be applied as one continuous coat.

There are situations where use of dehumidification is essential. An example is painting the tube sheet of a heat exchanger. The high-performance products commonly used in this situation must be put on in one application over the entire surface. Therefore, all the blasting must be completed, the plugs pulled from the tubes, and clean-up performed before the coating can be applied. Several days are usually required, so dehumidification is a requirement and not an option in this situation.

Dry air is also essential when blasting with steel abrasives. Moisture can condense in the pot when the unit cools overnight, causing the steel abrasive to rust. Dehumidification equipment keeps the steel abrasive dry and is an essential component of the blast equipment set-up.

Owners benefit from many of the items mentioned above. Work can be completed in a timely manner so that the loss of use of the facility is reduced and quality of work is improved.

Conclusion

Dehumidification lowers the moisture content in air to control corrosion of the blast-cleaned surface and to prevent moisture condensation on newly applied coatings. Proper dehumidification can keep a blast-cleaned surface from rusting for at least a week under most ambient conditions. Dehumidification can also be used for drying concrete prior to painting and is essential for keeping steel abrasive from rusting.