Chapter 2.11
Dehumidification During Coating Operations

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Introduction

Dehumidification is the process of removing moisture from air in enclosed spaces to reduce its humidity, while depressing the dew point significantly below the surface temperature. Thus, water will not condense on surfaces or otherwise cause adverse effects during surface preparation and coating operations.

The technology of dehumidification and temperature control in enclosed spaces continues to change rapidly and be more commonly used during coating/lining operations to enhance working conditions and performance and to reduce costs. This chapter describes how dehumidification can best be utilized for this purpose.

Benefits of Dehumidifying Enclosed Spaces

Dehumidification of enclosed spaces may provide several benefits during surface preparation and coating operations, as described in the paragraphs below. It may also improve productivity by increasing worker comfort and reducing fatigue.

Controlling Rust Bloom

Reducing relative humidity below a critical level can control rust bloom for several days to permit an entire tank to be abrasive blast cleaned before priming. Typically, rust bloom will be prevented from forming on an abrasive blast cleaned steel surface with a dew point 15 to 20°F (9 to 12° C) below the prevailing surface temperature and a relative humidity not to exceed 55%.[1] Surface contamination will lower the critical relative humidity.

Preventing Moisture Condensation on Uncured Coatings

Most coating specifications require that the steel surface temperature be at least 5°F (3°C) above the dew point before abrasive blast cleaning or applying coating to prevent moisture condensation. The same criteria may be required for a period of several hours after completing the application to prevent moisture from condensing on the incompletely cured coating. The dew point can be easily reduced by dehumidification.

Effects on the Curing of Coatings

Dehumidification can control the following effects of moisture on coatings:

- Ethyl silicate inorganic zinc-rich coatings require moisture for curing, while high humidities may retard the curing of water-borne inorganic zinc-rich coatings.
- Moisture-curing polyurethanes require a relative humidity range of 30 to 75% for optimum curing.[2]
- High humidities may retard the curing of water-borne coatings.
- High humidities can cause amine blush or carbamation (clouding) of amine-cured epoxy coatings.[3] U.S. Navy specifications require a 50% minimum relative humidity during application and curing of solvent-free epoxies.[4]

Removing Excess Moisture from Concrete

Excess moisture in cured concrete may cause blistering of coatings.[5] Dehumidification can remove this water effectively.

Definitions of Commonly Used Terms

Absorbant. A desiccant, such as lithium or sodium chloride, that undergoes a reversible chemical or physical change as it absorbs moisture.

Adsorbant. A desiccant, such as silica gel, that reversibly absorbs moisture like a sponge without physical or chemical change.

Dehumidification. The removal of moisture from the air.

Desiccant. A material used to absorb/adsorb moisture from the air and later release it when heated.

Dew Point. The temperature at which air becomes saturated with water (when the air is 100% relative humidity). Below this temperature, moisture condensation on surfaces will occur.

Flash Rusting. Steel rusting that occurs within

minutes to hours after surface cleaning. It is accelerated by salt contamination and high humidities.
Relative Humidity. The ratio of actual pressure of existing water vapor to the maximum possible (saturation) pressure of water vapor in the atmosphere at the same time, expressed in percentage.
Rust Bloom. See **Flash Rusting**.

Measuring Environmental Conditions

There are several instruments available for measuring relative humidity, dew point, and temperature. Each instrument has different levels of accuracy.

Psychrometers

A psychrometer is an instrument used to determine relative humidity and dew point by measuring the difference (depression) in readings from dry to wet bulb thermometers. There are three basic types: the sling psychrometer, the psychrometer with thermometers and a battery or electrically powered fan, and the battery-powered, digital psychrometer. These are described in ASTM E 337.

Today, the sling psychrometer is the most common in industrial coating work.[6] It utilizes a wet bulb (in a clean cotton wick saturated with distilled water) and a dry bulb thermometer that are spun rapidly through the air until constant readings are reached on each. Typically, the relative humidity and the dew point calculated from their measurements will vary about 5% from actual values.

Psychrometers with fans blowing air across the wet and dry bulb thermometers require about two minutes for stabilization. These instruments have advantages over the sling psychrometer of (1) being able to get closer to the surface being cleaned or coated and (2) being easier to use in tight places.

The digital psychrometer operates much more quickly than other psychrometers, requiring only 1 to 2 seconds for each measurement. It also does not require water for a wet thermometer bulb, and some store measurements for later retrieval.

Psychrometric charts must be used to relate thermometer readings to relative humidity, dew point, or absolute amount of moisture in the air. These charts may appear to be complex but are really straight forward to use.

Electronic Hygrometers

Electronic hygrometers are also available for measuring moisture conditions in air. The accuracy, reproducibility, and response time of these instruments vary widely, so that their readings may be no more accurate than good psychrometer measurements.

Surface Temperature Measurements

Bimetallic magnetic surface-contact thermometers are widely used during industrial coatings operations. They are inexpensive instruments that require calibration for accuracy.

Electronic surface-contact thermometers are inexpensive and feature a faster response time than the bimetallic magnetic surface-contact thermometers. Neither these thermometers can be used to monitor surface temperatures as during coating.

Infrared instruments for measuring surface temperatures do not have to remain in contact with the surface during measurement and thus can be used during coating operations. They are more costly than other thermometers but are much more convenient.

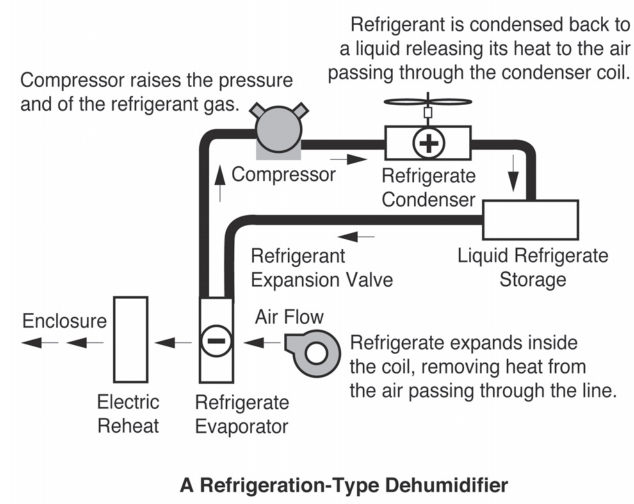

Figure 1. Refrigerant dehumidifier.

Types of Dehumidification Equipment

The dehumidifiers currently used for industrial purposes are described below.

Direct-Expansion Refrigerant Dehumidification

In the refrigerant method of dehumidification, ambient air is circulated over refrigeration coils at a significantly lower temperature. As the cooled air reaches its saturation point, the moisture is condensed, collected, and removed from the system. The refrigerant method provides cooling as well as dehumidification, and thus on hot days, is sometimes used with the desiccant system to reduce the temperature. This system is not recommended when outside ambient air temperatures are below 65°F (18°C) and the dew point difference between the surface temperature and the ambient interior air is specified as 45°F (27°C), because water may freeze on the coils. Typical refrigerant dehumidification equipment is shown in **Figure 1.**

Desiccant Dehumidification

The desiccant dehumidification system utilizes solid or liquid materials that have a high affinity for water that they can adsorb from the air. The water can later be removed by heating and the desiccant regenerated for reuse. For liquid desiccants, the air is passed through the liquids; for solid desiccants, granular beads or fixed desiccant structures are used in automated machines. The most commonly used desiccants are silica gel and lithium chloride, both become hydrated while removing water.

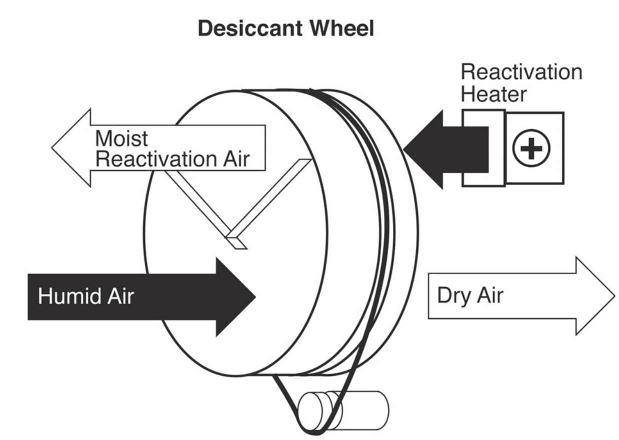

Figure 2a. Desiccant principle.

On large coating/drying projects, modern dehumidification equipment uses a special rotating wheel coated with the silica gel desiccant. As the moist air passes through the wheel it is adsorbed into the desiccant. As the wheel rotates past a set of seals, hot air from the reactivation heater is blown in the opposite direction, drying and reactivating the silica gel. The react air can be heated in various ways: electric heaters, steam coils, or natural or propane gas-fired heaters. The react air is hot and wet—120°F and 90–100% relative humidity. This react air must be discharged out of the enclosed space and away from the supply air intake. Silica gel desiccant is preferred as there is no chance of chlorides getting into the produced air stream. The reaction of drying the silica gel typically raises the temperature of the processed air stream by 10 to 15°F (8 to 12°C). These units are effective for dew point depression at all times of the year. Some cooling may be desirable in warm climates. The desiccant principle and typical desiccant dehumidification equipment are shown in **Figures 2a and 2b.**

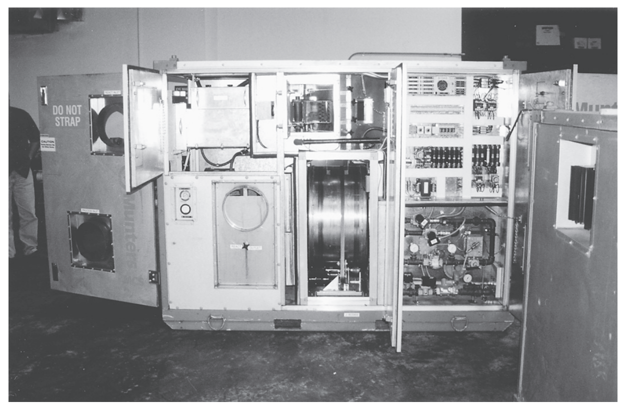

Figure 2b. Typical desiccant dehumidification equipment. Courtesy Munters MCS.

Combined Refrigerant and Desiccant Dehumidifier Systems

By pre-cooling the air and condensing some of the moisture before passing it through a desiccant, maximum efficiency in dehumidification is often achieved. It will also reduce the number of air changes necessary to maintain a 15°F–20°F (8–15°C) dew point difference between the internal surfaces and the internal ambient air temperature.

Choosing the Best Type of Dehumidifier for a Job[7]

Some criteria for selecting the best type of dehumidifier for a particular job are:

• Refrigerant dehumidifiers are more economical than desiccant dehumidifiers at high air temperatures and humidities. They are seldom used at dew points below 40°F (4°C) because condensed water freezes on the coils.

• Refrigerant dehumidifiers are more efficient when drying air to saturated conditions, and desiccant dehumidifiers are more efficient when drying air

to low humidities.
• The refrigerant and desiccant dehumidifiers can be used together most economically by utilizing the advantages of each. The relative costs of electrical power and thermal energy will often determine the most economical mix.

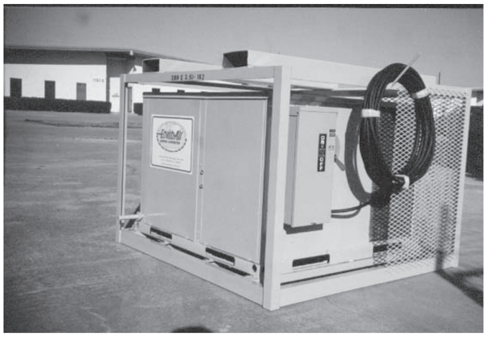

Figure 3. Enviro-Air 1000 CFM DH unit. Courtesy Enviro-Air Control Corp.

Closed-Loop System

A closed-loop dehumidification system is one in which the exiting air is routed through an appropriate filter media and used as feed air for the dehumidifier.

During abrasive blast cleaning, the exiting air contains particulate matter consisting of spent abrasive, paint and rust particles, etc. This matter must be filtered through a dust collector before the air is passed through the dehumidifier and recirculated or exhausted. During coating application, solvent vapors will also enter the exiting air. These must be removed from air to be recirculated because the solvent fumes may be unhealthy, combustible, retard curing, and damage the desiccants.

Solvent fumes may be adsorbed on charcoal filters that must be replaced periodically, as their capacity is reduced. The increased use of high-solids (low-solvent) coatings may reduce this problem significantly.

Dehumidification Limitations in Producing Quality Air

While dehumidifiers may introduce copious quantities of fresh air into an enclosed space, the quality of the resultant air does not eliminate any requirements for respirators associated with the coatings being applied. Despite many changes of air, residual solvent will remain in the working area during the curing. Similarly, respirators or dust masks required by the material safety data sheets of the abrasive and coating manufacturer should be used during abrasive blast cleaning and coating, whether or not dehumidification is being conducted at the time.

The introduction of large volumes of dehumidified air into the work area may disturb blasting debris and reduce visibility, even though dust collects or dust socks are being used to remove these particulates. Therefore, the dust collectors must be properly sized to perform effectively with the dehumidifiers so that no more outside air is introduced than can be handled by the collectors. During inclement weather, the efficiency of the dehumidifier can be increased by reducing the air flow of the dust collector.

Sizing Dehumidification Equipment

There are many factors involved in properly sizing dehumidification equipment for a specific job. In addition to the air flow rate through dust collectors, other factors affecting the sizing include the season, the weather, the location, the volume of enclosed air, the number of enclosure openings, the distance from the dehumidification equipment, and the presence of other equipment (e.g., in-line electric heaters and chillers) being used in conjunction with the dehumidifier.

Typically, fewer changes of air are required for larger volume enclosures. Enclosed spaces that are more air-tight require less dehumidification. A dehumidifier's ability to produce volumes of dehumidified air in ft^3/min. is specified on the equipment's data plate, as well as in the equipment data sheet.

Equations for Calculating Dehumidifier Air Flow Capacity

The necessary air flow capacity of a dehumidifier for a specific number of air changes per hour can be calculated using equation (1):

$$(V_1)(AC)/60 = X \qquad (1)$$

where:
V_1 = the internal volume in cubic feet of the enclosed space minus the
volume of all obstructions within the space
AC = the specific number of air changes per hour
X = the air-flow capacity in cubic feet per hour that corresponds to the specified air change rate

If the metric system is used, the necessary capacity of a dehumidifier for a specific number of air changes can be calculated using equation (2):

$$(V_1)(AC) = X \qquad (2)$$

where:
V_1 = the internal volume in cubic meters of the enclosed space minus the
volume of all obstructions within the space
AC = the specific number of air changes per hour
X = the air flow capacity in cubic feet per hour that corresponds to the specific air change

Example of Calculation of Dehumidifier Capacity Requirements

Calculate the required capacity of a dehumidifier to dehumidify a cylindrical tank 100 ft in diameter (50 ft in radius) and 10 ft in height for 4 air changes per hour.

Step 1. Volume of tank (V_1) = $\pi r^2 h$

where
r = radius
h = height
Volume of tank (V_1) = 3.14(50)(50)(10) = 78,500 ft^3

Step 2. Using equation (1), dehumidifier capacity (X) = 78,500(4)/60 = 5,233 ft^3/hr

Figure 4. DH equipment installed beside shrouded tank. Courtesy Enviro-Air Control Corp.

Installing Dehumidification Equipment

Ideally, the dehumidifiers should be placed as close to the enclosed area as possible to reduce losses of air pressure by friction or leaks in lengthy air ducts. This is especially important when in-line heaters are used, because the heat can be readily lost over long distances, even when insulated ducts are used. High-voltage electric heaters and those utilizing indirect fired natural gas or propane inline heaters can be dangerous to workers who are not fully trained or do not properly utilize their training. Indeed, local government agencies may require operating permits for dehumidification equipment.

The air duct from the dehumidifier should be carefully placed in the enclosure for optimal air flow within the space to assure removal of water from all areas. Alignment of the duct along tank walls will cause the air to flow in a funnel pattern and permeate all areas as it circulates around the enclosure. There must always be an exit point for air in the enclosed area in order to affect an air change.

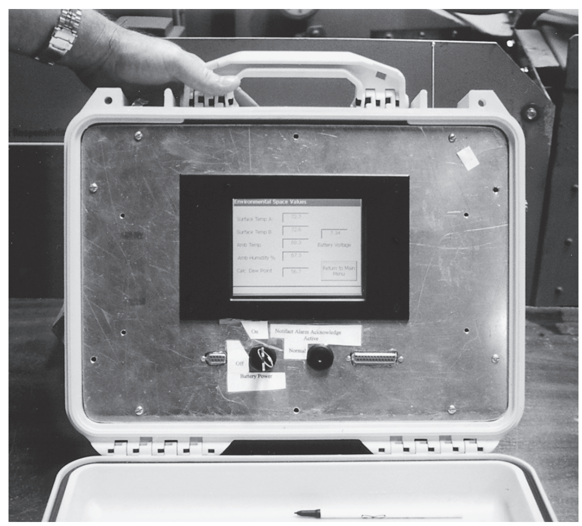

Figure 5. Exactaire instrument for monitoring environmental conditions in enclosure. Courtesy Munters MCS.

Monitoring

In addition to monitoring the relative humidity, dew point, and temperature, as described earlier, carefully monitor the equipment itself in the event that unexpected shut-downs occur from mechanical problems or fluctuations in the power source. Dehumidifiers have multiple banks of fuses that can shut down the equipment when power fluctuations occur.

Once a dehumidification unit shuts down, the air conditions may change so as to permit rust blooming of uncoated steel or adverse effects on uncured coatings.

A new remote monitoring system currently available can inform responsible individuals when control of space conditions are lost, when equipment fails, or when fuel is low. It can also stop and start the D/H equipment, as the dew point spread indicates, to save fuel.

Figure 6. DH unit with dust collector in place. Courtesy Enviro-Air Control Corp.

References

1. SSPC-TR 3/NACE 6A192. *Dehumidification and Temperature Control During Surface Preparation, Application, and Curing of Coatings;* SSPC: Pittsburgh, 2001.
2. Hare, Clive H. *Protective Coatings: Fundamentals of Chemistry and Composition;* Technology Publishing Company: Pittsburgh, 1994, pp 252-254.
3. Keehan, David; Wyatt, Charles H. Humidity—It Affects More Than Just Surface Preparation. In *Proceedings of SSPC '99,* pp 323-334.
4. Dehumidification. In *Procedure Handbook: Surface Preparation and Painting of Tanks and Closed Spaces;* SSPC: Pittsburgh, 1999, pp 41-58.
5. Schnell, Don J. Utilizing Desiccant Dehumidification to Remove Excess Moisture from Concrete. In *Proceedings of SSPC '00,* pp 25-28.
6. *The Inspection of Coatings and Linings;* Bernard R. Appleman, ed.; SSPC: Pittsburgh, 1997, pp 365-366.
7. *The Dehumidification Hamdbook, 2nd Edition;* Lewis G. Harriman III, ed.; Munters Cargocaire: Amesbury, MA, pp 3-21.

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