DEHUMIDIFICATION AND OTHER ENVIRONMENTAL CONTROLS FOR COATING PROJECTS

A **JPCL** eBook

Dehumidification and other Environmental Controls for Coating Projects

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Contents


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Introduction

This eBook consists of articles from the *Journal of Protective Coatings & Linings (JPCL)* on dehumidification and other environmental controls for coating projects. Authors' affiliations are listed as they appeared when the articles were originally published in *JPCL*.

Photos this page and cover courtesy of DRYCO

By Robert Ikenberry
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Editor's Note: This article apeared in the supplement to JPCL *in August 2013.*

Environmental controls are used for many reasons, including making a jobsite suitable for painting and blasting in extreme conditions. iStock

IT'S ALL RELATIVE
Advances in Environmental Controls for Coating Work

Painting projects use environmental controls for several purposes, including the following:

1. Containment to enclose hazardous operations like lead abatement, protecting the environment outside the work zone;
2. Containment for ventilation to provide conditions conducive to proper surface preparation, safe working conditions, and paint curing. Often combined with #1 above; and
3. Containment and ventilation with humidity and/or temperature control to retain the blasted surface until the entire space (or at least a larger portion) can be coated monolithically, and/or to allow for proper cure of reactive coatings and for worker comfort and productivity. Always combined with #2 above and often #1 as well.

The items on the previous page are not the only reasons for, or benefits of, using environmental controls. Ventilation may be required to control both flammable and toxic concentrations of solvent evaporating from high-performance coatings. In extreme weather (both hot and cold), local environmental controls to the workers' headspace may be necessary for productivity and even safety.

Attention to controlling workspace environments has increased over the decades, driven by factors such as regulations, specifications, and the focus on quality. This article focuses on key equipment and practices for controlling the environment, as well as some advances in them over the past three decades.

Back in the Day

I remember my first experience with "environmental controls." It was the mid-1970s, and we had a contract to blast and paint a highway overpass on a busy freeway. (In retrospect, I'm sure the existing paint contained lead.) The steel girders extended in a sweeping curve past the active roadway as part of a complex interchange, and we could work on most of the span during the day. We wanted to put up some tarps to contain the painting operation so we wouldn't have overspray claims from paint landing on passing cars. (The San Francisco Bay Area is notoriously windy, and the paint system specified at the time was slow drying and a known overspray risk.)

The question then became: "Do we keep the tarps up while we blast?" As I recall, California had fairly recently introduced regulations limiting the amount of visible dust from outdoor abrasive blasting. Putting up containment would significantly reduce the total amount of dust in the air from blasting, but it would be coming from fewer (basically point source) locations at the ends of the containment. The regulations dealt with the obscuration of the visible dust plume (Ringlemann Scale visual test), and concentrating the dust cloud would mean we were more likely to get cited for too much (too dense a plume) dust. So we took the tarps down to blast! Regulations sometimes have unintended effects…but no containment was probably actually safer for our painters at the time. Our approach today would have to be very different.

Containment

With some exceptions, containment, in my experience, hasn't changed that much in the past 30 years, but its use has. The use of containment has often been driven by regulations for protecting the environment and the public from exposure to silica sand, as well as exposure to lead and other hazardous materials and debris. As more hazards are identified in coating and blasting materials, containment is more frequently specified. Also driving the use of containment are the need to avoid overspray, as in my first experience, and the need in many plant interiors to protect sensitive equipment, other plant workers, and products from blasting or painting debris.

My first use of it involved hanging tarps, a practice still done. There also have been, for quite some time, highly engineered containment systems, some built on sophisticated platforms for bridges and offshore structures, and others engineered for interior use. SSPC developed a guidance document for various levels of containment, SSPC-Guide 6 (CON), Guide for Containing Surface Preparation Debris Generated during Paint Removal Operations (first issued in 1992 as SSPC-Guide 6I, part of a supplement to SSPC's Volume 2, *Systems and Specifications*).[1] This document is well-known and used. Specifications for painting projects now often identify the level of containment based on Guide 6. In my experience, the application of containment has changed significantly—its use has increased over the years, not just in frequency, but higher levels of containment are now specified. Ventilation is generally needed, often including dust collection, exhaust, and controlled make-up air. Here is where heating and, sometimes, cooling or dehumidification, come into play. Designing and setting up the containment and its associated equipment are project-specific. It is always a balancing act with any containment, so that its use is safe for workers, the public, and the environment. We don't want to create a situation like the one in my first experience, where not using containment probably was safer for the workers, but at the expense of the unsuspecting public.

Understanding the Mechanics of Humidity: Dew Point, Water, and Vapor Pressure

Before I even start to talk about humidity and its control for blasting and coating work, I'd like to point out that in my experience, over the past 30 years, humidity, as well as its control and measurement, has not been well understood. So I will try to explain the

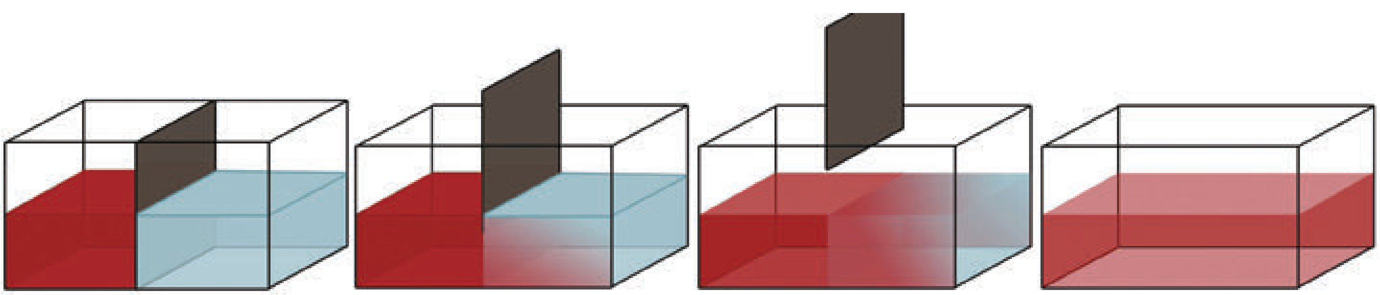


Fig 1a: We expect dehumidified areas (pale blue) and saturated areas (red) to mix like water in a fish tank—when you remove the divider, one color water slowly diffuses into the other.

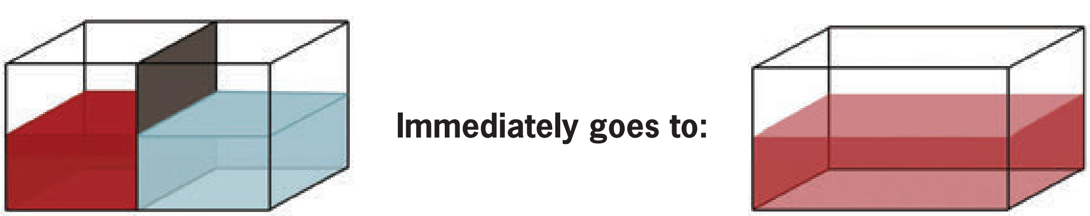


Fig 1b: In reality, it's more like one area has a vacuum (pale blue) and the other side has normal air pressure (red) . . . and when the divider is pulled away, the water instantly changes color. Graphics: Lisa Tseng

basics of the topic and its associated technology as well as note some changes in equipment and practice over the past 30 years.

For coatings, or comfort, it's usually not the total amount of water in the air (humidity) that matters; it's the Relative Humidity (RH) that's important. That is, RH is how much water is currently present in the air compared to how much water vapor the air can hold. When the air is fully saturated (100% RH), liquid begins to condense, making dew on surfaces (dew point) and even creating fog in the air. This amount of vapor capacity varies widely by temperature. At sea level, the amount of water in fully saturated air at freezing (32 F, 0 C) is about 27 grains per pound of dry air (4 grams of water per dry kilogram of air). At 75 F (24 C), it's about 131 grains (19 grams), and at 120 F (49 C), it's over 566 grains (80 grams). That's almost 20 times as much moisture capacity in really hot air! So one way to reduce RH is to heat the air. If you don't add any water, 100% saturated air at 32 F becomes much less than 10% RH when heated to 120 F. This may be an extreme case, but heating with indirect fired heaters is a very effective way to reduce RH.

Now let's focus on controlling the environment for coating work. The problem is that heating the air is a relatively ineffective way to heat the surface, and when we are talking about paint application and curing conditions, it's typically the conditions at the surface that are of interest. When we specify that temperatures need to be X degrees above the dew point, we mean the temperature at the surface of the steel.

A rule of thumb, then, is that RH changes by a factor of two for each 20-degree F change in temperature. In other words, if pressure and total moisture don't change, saturated air (100% RH) at 50 F, when heated to 70 F, would be around 50% RH; and further heating to 90 F would result in RH of approximately 25%. This same rule of thumb explains why, if you keep the dew point at least 20 degrees F below the steel temperature, you can generally hold your blast indefinitely. (You can hold the blast for days at least, probably weeks, if the air and steel are clean.) With a 20-degree F (11-degree C) dew point spread, RH at the steel surfaces will be about 50%, and corrosion (flash rusting) will be drastically reduced. To hold a blast, keep the surface of the steel 20 degrees F above the dew point.

For painting, two additional dew point considerations generally apply. To paint, you need to avoid condensation on the surface of the steel so that you don't paint wet surfaces. You also typically want to avoid dew (liquid water) condensing on the wet paint. Keeping the steel surface about 5 degrees F (3 degrees C) above the ambient air dew point assures that you avoid both of these undesirable conditions. (Dew won't condense on steel surfaces until they are at or below the dew point, but starting painting when there is a 5-degree F spread accounts for the inevitable variations in conditions from place to place or over short intervals of time. What you measured may not reflect the "worst case" conditions on the project.)

Dehumidification is somewhat analogous to creating a vacuum. You're trying to suck just one component out of the air—the water. With gases and solutions, the partial pressure (in this case, vapor pressure) can be considered a bit like actual pressure, say in a tank. Vapor pressure is just another way of expressing dew point temperature. Both are absolute measures of the water vapor in the air. When one changes, so does the other. The water vapor very much wants to equalize the "partial pressure" and will flow from areas of high vapor pressure to low vapor pressure with surprising rapidity. Consider first a transparent box, like a fish tank, with a removable divider down the middle. You might at a gut level consider the situation somewhat like filling one side of the tank with red colored water and the other side of the tank with clear water. Carefully remove the divider, and the color

Not Getting PSYCH'ed Out— How To Read Psychrometric Charts

By Robert Ikenberry, California Engineering Contractors Inc.

Maybe it's because most people pronounce "psycho" in the name, or maybe it's the "metric" that turns off Americans, but put the terms and the chart together, and you have a weird, distorted graph that drives people crazy and most find incomprehensible, now, as well as over the past 30 years, perhaps. But it doesn't have to be quite that complex. Let's get started with a couple of definitions and a slightly simplified chart.

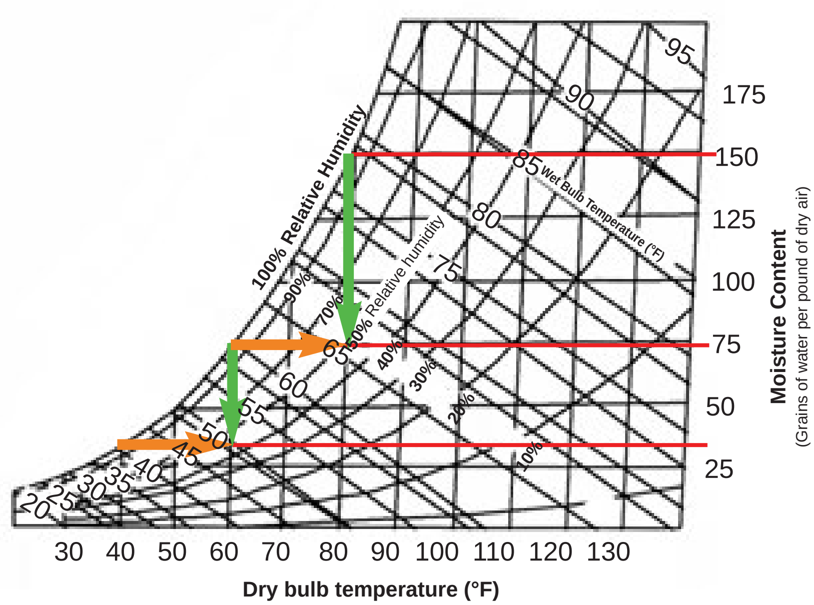
"Dry bulb temperature" refers to the reading of a thermometer exposed to the ambient air but not direct sunlight or moisture. This is what we think of as a "normal" temperature reading. When the weatherman says "it's 78 F," he means dry bulb temperature.

"Wet bulb temperature" refers to the reading of a moistened thermometer exposed to moving air. Wet bulb thermometers generally have a sock or "wick" of cloth saturated with water surrounding the thermometer bulb (so that it's "wet").

Dry bulb temperatures are listed at the bottom and constant temperature is represented by a vertical line on the chart. On the left side of the table, the curving edge labeled "100% Relative Humidity" represents a saturated state, and is the most moisture the air can contain. Any additional moisture in the air would precipitate out as rain or fog. The values are in grains of water per pound as shown on the axis on the right. For the purposes of illustration, the horizontal orange and red lines highlight the amount of water in saturated air at 40, 60 and 80 F. Green lines highlight reducing water content from saturated (100%) to 50% RH. Orange arrows at 40 and 60 F highlight increasing temperatures from saturated to 50% RH.

Notice that hot air can hold a lot more water vapor. If the steel temperature is 20 degrees F above the dew point, the RH is about 50%. The psychrometric chart shows why. Look at the total amount of water in 40 F *saturated* air. It's about 35 grains of water per pound. Now look at the amount of water in 60 F *saturated* air. It's about 74 grains of water. So if the temperature is 60 F and the same amount of water is present as in saturated 40 F air, the RH is just under 50%. Moving up to 80 F air, it can hold about 155 grains of water, just over twice as much as 60 F air. Put it another way, if we heat saturated 60 F air to 80 F without adding water, the RH goes down to just under 50%. Moving to the right on the chart indicates heating without changing water content (the grains of water stay the same). Moving down on the chart indicates removing water while the temperature remains the same (dehumidification).

Graph courtesy of SSPC, from SSPC-TR 3/NACE 6A192.[4]



will mix into the other side, eventually making everything a uniform pink, but it will take a while (Fig. 1a, p. 3).

Unfortunately, dehumidification is really more like taking our divided tank and, with our red air in one side, trying to vacuum out most of the air from the other side. If we have any significant containment leaks, it's as if we just started to remove the barrier… and wham! Instant pink air, all over the tank (Fig. 1b, p. 3).

The air will impede the flow of the water vapor a little bit, but, remember, water molecules are actually smaller and lighter than nitrogen or oxygen molecules, so the flow of water vapor from areas of high moisture content to areas of low moisture content is a strong wind. It's difficult to restrict. This frantic desire by gasses to equalize pressures of all components, including RH (water vapor), is one reason most successful dehumidification applications are on tanks or vessels where there is already a solid mechanical barrier between inside and outside air, and the make-up vents are highly controllable. Humidity control is possible in a well-constructed, well-sealed containment, but unlike ventilation for lead dust control, where negative air pressure inside the space is desirable, for dehumidification you want to maintain a positive pressure inside the dried space. Therefore, sometimes these goals are in conflict.

Dehumidification: Types and Advances

The fundamental technology underlying desiccant dehumidifiers hasn't changed much in the past 30 or 40 years. Units that perform the same basic functions were available in the 1970s. In fact, my prior employer used a twin tower desiccant dehumidification system on our compressed air supply on a project in Hawaii in 1978. Conceptually the same as dehumidification for ventilation air, this compressed air system provided -40 F dew point air for blasting.

There are two basic types of dehumidification equipment: desiccant and refrigeration. While the basic principles of operation haven't changed much, we will see that the need to increase energy efficiency and the electronic age have brought changes to dehumidification equipment.

Desiccant dehumidifiers generally use a large wheel containing a desiccant material, which can absorb moisture from the air. Most of the wheel is exposed to the incoming air to be dried. A smaller portion of the wheel (±25%) is subjected to a reverse flow of heated air, which dries out and reactivates the desiccant. By slowly rotating the wheel, the dehumidifier can operate continuously. Residual heat in the wheel after reactivation tends to heat the dried air going into your space.

The latest technology uses a small portion of the wheel to create a pre-heat/post-cool energy capture loop to reduce the energy demand of re-activation. This pre-heats the drying section of the wheel as it rotates into the purge area and cools the desiccant before it enters the process section, so the dry air coming out of the unit isn't heated as much, and more heat stays to reactivate the desiccant.

The other technology for dehumidification uses refrigeration dehumidifying units, or, more accurately, condensation dehumidifying units. Refrigeration dehumidifiers seem (to me) to operate a bit counter-intuitively. In order to dry the air, they cool it, driving up the RH. In fact, to work, they have to keep cooling the air until it exceeds 100% RH, or total saturation. At that point, the excess moisture collects on the cooling coils as condensation. After the condensed water runs off the coils, the air exiting the condensing section of a refrigeration dehumidifier is always saturated, or at 100% RH. Most units use electric heaters on the air exiting the condenser section to raise the temperature and lower RH. Since compressors on refrigeration units generate a lot of excess heat, some units use this heat to warm the cool air coming from the condensing section, saving energy over those that only use electric heat. Note this reheating does not change the dew point, which depends solely on the total amount of water vapor, but it does lower the RH of the discharged air.

The theoretical limit for refrigeration dehumidification would be an exit dew

General Planning for Ventilation

By Robert Ikenberry,
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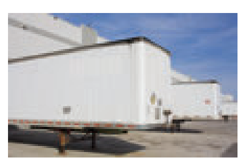
The following is for illustration purposes only and is not to be relied upon for worker or property safety, nor is it intended to represent legal or expert advice. Anyone working with flammable or toxic materials needs to consult the advice of appropriate experts (a certified industrial hygienist—CIH—or equivalent) to ensure regulatory compliance and adequate worker safety.

Let's pick a typical example: say that painting out the blast cleaned steel surfaces at the end of the day takes 10 gallons of epoxy with 80% solids by volume and all the volatiles are flammable solvents. That puts 2 gallons of solvent into the air, and, to be conservative, we assume that it all evaporates in the hour it takes to apply it.

Here's a simple calculation for a first approximation: with 2 gallons of solvent, each gallon will create about 23 cubic feet of solvent vapor (consider this a constant for typical paint solvents) at 100% solvent vapor, or 46 cubic feet, total. Typical LELs are about 1% by volume of solvent in air or a bit higher, so we assume that diluting the solvent vapor by 100 will put us below the LEL. That takes 4,600 cubic feet of ventilation air. The 1% is assumed to be the LEL, so to get to 10% of the LEL, we need to dilute by 10 times again, giving us 46,000 cubic feet. In order to assure complete mixing, without dead spots, we should apply a safety factor. Four to six times is often considered a reasonable range to take care of incomplete mixing, so we multiply our current value by 5 and get a final fire-safe ventilation value of 230,000 cubic feet. Dividing our hour by 60 means we need to ventilate our paint area at the rate of 3,833 cubic feet per minute for the entire hour.

Two gallons of solvent, evaporated, fills half a typical portable toilet; dilutes at the LEL to fill two each 40-foot shipping containers; and to be fire safe, should be further diluted to fill an Olympic-sized pool.


X 23 CF/Gal =

46 CF X 100 =

4,600CF X 10 X 5 =


Flushing our 2 gallons of solvent with 230,000 cubic feet will eliminate fire hazards, but what about personal exposure safety? Let's say the flammable solvent was MEK (Methyl Ethyl Ketone or 2-Butanone). With an LEL of 1.4%, our calculations for fire risk were presumably conservative. The OSHA PEL for MEK is 200 ppm. Remember that 1% is 10,000 ppm, so when we got down to 10% of the PEL we are still at 1,000 ppm. To make the air safe for workers to breathe (assuming the same mixing safety factor), we have to add ventilation to bring concentrations down by another factor of 5 to 1,150,000 cubic feet of dilution ventilation in an hour. Now we have to move almost 20,000 CFM. And if our solvent were more toxic, like cumene, with a PEL of 50, we'd need almost 80,000 CFM to ensure our painters didn't need to wear respirators. To summarize:

Gallons X 23 = 100% solvent, X 100 = 100% LEL, X 10 = 10% LEL (theoretical), X 5 = 10% LEL with allowance for incomplete mixing. Total = 230,000 CF, a bit more than enough to fill a typical Olympic sized swimming pool. To get down below the PEL, 5 times more…

point of 32 F. When refrigeration DH units get close to a 32 F dew point, ice builds up on the cooling coils, so a realistic lower limit for drying air using a refrigeration dehumidifier is about 40 F dew point air.[2] If ambient temperatures are above 60 F all day, this provides the minimum 20-degree F dew point spread you need to hold your blast. Where there are large swings in temperature, such as the San Francisco Bay area, this can be problematic. With a 70 F daytime high temperature followed by a 50 F nighttime low, using a refrigeration dehumidifier under those nighttime conditions might result in a dew point spread of only 10 degrees F or less. This is not enough to ensure that flash rusting cannot occur, and you may come in the following morning to find that your blast has turned. Also be aware that steel surfaces exposed to clear nighttime skies can cool below the ambient temperatures due to the heat-sucking characteristics of the cold sky.

For both types of DH units, the major cost of operation is energy. Anything that reduces the total amount of energy required to remove a fixed quantity of water from the air is a plus. Recent technology advances focus on lowering the total energy costs of operation. Units described above scavenge heat that was previously wasted, improving the efficiency of current units. Advances in electronic controls and data sensing can also come into play. Using sensors that detect the temperature of the reactivation air exiting the desiccant wheel, current units can be set to adjust their operational cycles to turn off their reactivation heaters when not needed, the equivalent of cycling your air conditioner compressor. This avoids the cost of over-processing the air, or running the compressor section or reactivation heaters when they aren't required.

In some equipment, combined-cycle DH units may use both principles in a single unit, particularly where ambient temperature and humidity are both high, and lots of water has to be removed. While industrial applications don't generally recycle the air inside the conditioned space and therefore may not see as much savings, a study published in 2006 by the Florida Solar Energy Center testing a hybrid refrigeration/desiccant dehumidification system found that it used only about 25% as much energy as a refrigeration unit alone.[3] Incorporating a special blend of desiccants, these combination units first cool the air using typical refrigeration/condensation and then send the saturated, cool air through a desiccant. Since the RH at this point is high, it's relatively (no pun intended) easy for the desiccant to grab a substantial portion of the water. The waste heat from the refrigeration compressor is then used to regenerate the desiccant wheel, resulting in much greater efficiency.

Another of the recent high-tech advances for field industrial humidity control is remote sensors that can be placed in the conditioned space. They report continuously and wirelessly back to the dehumidifier and to the web. These monitors can provide two advantages.

• By continuously monitoring conditions in the space, they can act as a hygrostat (humidistat) to efficiently control the DH units and to alert the contractor when there is a problem like a generator running out of fuel and shutting down.

•More often, the units' primary purpose is to demonstrate that appropriate conditions were maintained throughout surface preparation, coating, and curing. They give the owner assurance that the specification requirements were met and are often instrumental in preserving the long-term warranty from the coating supplier. Warranties may be subject to challenge or dispute if the owner and contractor can't show that the application conditions were adequately controlled.

Cleaner, drier surfaces are also more resistant to flash rusting. SSPC's Technical Report 3 (SSPC TR3/NACE 6A192)[4] indicates that RH and surface cleanliness are both critical factors in flash rusting. For perfectly clean iron, corrosion doesn't start until about 90% RH. But if there is a bit of sulfur dioxide (SO_2—a component of smog) present, rusting will occur, beginning at about 65% RH. Salt (sodium chloride—NaCl) will lower the level at which rusting can occur to 55% RH. So the cleaner the surface (and the air) are, the more resistant the steel is to flash rusting, and RH levels below 50% will prevent rusting in the presence of some of the more common contaminants. Technical Report 3 is a good follow-up to this introductory article if you are looking for more information on dehumidification and temperature control.

Many contractors are intimidated by calculations (math!) for dehumidification (DH) and ventilation, but they don't have to be that complicated. First, suppliers will be happy to assist with calculating requirements and sizing equipment. Second, a few basics will help you understand the calculations. The sidebar, "Not Getting Psyched Out," will show you the basics of determining RH and reading those mysterious charts for RH (p. 5). Third, there are instruments that will help you monitor RH, wind speed, and other conditions on your jobsite.

Portable instruments for wet and dry

Heat Index Risk Chart

Air Temperature	Relative Humidity 40	45	50	55	60	65	70	75	80	85	90	95	100
80°	80	80	81	81	82	82	83	84	84	85	86	86	87
82°	81	82	83	84	84	85	86	88	89	90	91	93	95
84°	83	84	85	86	88	89	90	92	94	96	98	100	103
86°	85	87	88	89	91	93	95	97	100	102	105	108	112
88°	88	89	91	93	95	98	100	103	106	110	113	117	121
90°	91	93	95	97	100	103	105	109	113	117	122	127	132
92°	94	96	99	101	105	108	112	116	121	126	131		
94°	97	100	103	106	110	114	119	124	129	135			
96°	101	104	108	112	116	121	126	132					
98°	105	109	113	117	123	128	134						
100°	109	114	118	124	129	136							
102°	114	119	124	130	137								
104°	119	124	131	137									
106°	124	130	137										
108°	130	137											
110°	136												

Apparent Temperature

Adapted from noaa.gov[7]

"Feels like:"

80-90°F – Exercise Caution

91-103°F – Extreme Caution

104-124°F – Danger

125°F + – Extreme Danger

bulb temperature measurement are readily available and much faster and more user friendly than old sling psychrometers with their wicks and thermometers. Manufacturers have adapted digital technology to all kinds of measurement instruments for environmental control. For example, one manufacturer's line of instruments adds wind speed measurements (although they are usually not sensitive enough for the low 10–50 fpm [0.1–0.5 mph] flows generally found in containments) and put a portable weather station in the palm of your hand for a few hundred dollars. Wind speeds, dry bulb, wet bulb, dew point, RH, even barometric pressure are all instantly available. Just add a surface temperature thermometer and you are fully instrumented.

What's more, if you want to keep track of environmental conditions on your project, or calculate how much DH capacity you need, numerous free smartphone apps are available. Just run a search on your phone or tablet.

Environmental Controls for Workers

Holding a blast and ensuring proper coating curing conditions are not the only reasons to consider environmental controls. Worker safety and productivity can also dictate controlling the environment. Making the job environment safer and more comfortable usually makes workers more productive.

First, ventilation is often needed for visibility. Abrasive blasting, especially when using mineral abrasive or preparing concrete, can generate high levels of dust. Respiratory protection can reduce exposures to silica and heavy metals, but if workers can't see, especially for exiting in an emergency and knowing where their coworkers are, then the conditions are unsafe.

Few objective guidelines exist for field dust extraction ventilation. The one set of published values often adopted by CIHs as a recommendation for lead work areas is 100 linear feet per minute cross draft and 50 linear feet per minute downdraft.[5] These guidelines apparently originated with blast and spray booth design and are very hard to achieve in normal-sized work enclosures (and usually impossible in large tanks). In my experience, these ventilation rates are overkill and can't easily be achieved in practice on most jobs (particularly if heating or DH is in place).

NFPA 33 is sometimes referenced as ventilation guidelines for field enclosures for painting.[6] This is clearly an inappropriate reference, because the standard is intended for spray application using flammable materials in permanent structures. Section 1.1.5 states, "This standard shall not apply to spray processes or applications that are conducted outdoors." Section 1.1.6 further states, "This standard shall not apply to the use of portable spraying equipment that is not used repeatedly in the same location." Annex A's Explanatory Material on section 1.1.5 further clarifies: "This standard does not cover … bridges, tanks or similar structures."

Further, these rates generally aren't needed for visibility control. For example, consider a typical steel structure work enclosure, 15 feet high by 25 feet wide by 100 feet long; it has a face area of 375 ft^2. Ventilating the length of this containment at 100 linear feet per minute would require 37,500 CFM, and would result in one air change every minute. In this instance, a ventilation rate of 10 to 12,000 ft^3 per minute is probably more achievable, and reasonable, and results in 16 to 20 air changes per hour. For large tanks, it may be practical to get only 4 to 6 air changes per hour during blasting. You do still need some air movement for visibility—for structure containments, airflows of less than 10 linear feet per minute will generally not be effective and will result in an excessively dusty environment.

In addition to visibility, real-world ventilation measures need to ensure an environment with solvent vapor levels of less than 10% of the LEL (Lower Explosive Limit) at all times whenever flammable solvents are sprayed. Consideration should also be given to using ventilation to reduce exposures to toxic solvents to levels below PELs (Permissible Exposure Limits) whenever possible. Note that PELs can be 10 to more than 50 times lower than the flammability guideline of 10% of LEL. There can be a lot of confusion about using dilution ventilation to eliminate fire risks and reduce toxic exposures. The exact calculations are complex, and the mixing of airflows around complex structures and even in open spaces like tanks makes it very difficult to model exactly. Note well: the best way to ensure levels below 10% of the LEL is to monitor with a calibrated meter. Use your CIH for specific advice. But there are some simple rules of thumb that can be applied to give a reasonable assurance of fire and worker safety, as described in the second sidebar, "General Planning for Ventilation" (p. 7).

Another aspect of worker comfort also impacts safety and productivity. Heavy exertion in a hot and humid environment may be dangerous, especially to those who aren't acclimated to the heat. Special consideration should be given to blasters because their protective suits can increase heat exposures significantly. Heat illness risks have been a recent special focus of safety regulators, with California's Cal/OSHA leading the way.

A heat index risk chart is shown on p. 9. Many combinations can be risky. Note that the "Danger area" encompasses 96 F at 50% RH (feels like 108 F), or 90 F at 70% RH, or 86 F at 95% RH. Reducing 86 F air from 95% RH (feels like 108 F) to 50% takes conditions out of the Danger zone all the way down to a relatively comfortable "feels like" 88 F. DH can be a big comfort and heat safety bonus. Actual cooling, of either the air in the entire enclosure or the air fed to the worker's hood, can be effective as well. To cool just workers, the most effective methods are probably vortex air coolers, which split a compressed breathing-air stream into hot and cold portions so that cool air can flood the worker's blast helmet. There are other lower-tech ways to cool workers too, from wearing vests with pockets for freeze-packs, to running coils of airlines through coolers filled with ice and water.

Conclusion

In summary, many more projects deal with environmental controls today compared to projects conducted three decades ago. Some of this change has been driven by regulations, particularly lead safety OSHA requirements; some of the increase has been driven by specifications, as owners recognize quality improvements result from dehumidification on tank linings; and some of the increases have been voluntary, as employers recognize productivity improvements from increased worker comfort. New technologies have particularly improved measurement of temperature and humidity and controls of equipment.

New technologies on the horizon promise still more sophistication in electronic controls, allowing 'set-it-and-forget-it' options for contractors who want their field crews to be able to focus on production. Nanotechnologies may offer enhancements in desiccants with improved zeolite formulations that are much more efficient absorbers of vapors and gaseous materials, including organic vapors. It may even be possible to allow recirculation of conditioned air during painting, with the proper scrubbers and air "conditioners." Stay tuned—more advances are surely on the way.

References

1. SSPC-Guide 6 (CON), Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations, SSPC: The Society for Protective Coatings, sspc.org, Pittsburgh, PA, 2012.
2. Don Schnell, "Sizing DH for Water Tank Lining Jobs," *JPCL* May 2011, pp. 20–26.
3. Charles J. Cromer, PhD, PE, Field Test of Combined Desiccant-Evaporator Cycle Providing Lower Dew Points and Enhanced Dehumidification, Florida Solar Energy Center (a research institute of the University of Central Florida), Cocoa, FL, 2006
4. SSPC-TR3/NACE 6A192, Dehumidification and Temperature Control During Surface Preparation, Application, and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces, SSPC/NACE Joint Technical Committee Report, SSPC: The Society for Protective Coatings (sspc.org), Pittsburgh, PA, 2000
5. ACGIH Industrial Ventilation Manual, American Council of Governmental and Industrial Hygienists, acgih.org, Cincinnati, OH
6. NFPA 33, Standard for Spray Application Using Flammable or Combustible Materials," National Fire Protection Association, Quincy, MA, 2011
7. National Oceanic and Atmospheric Administration (NOAA) Heat Index Chart (http://www.wrh.noaa.gov/psr/general/safety/heat/), Silver Spring, MD

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By Lloyd Smith
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The Basics of Dehumidification

Editor's note: This article appeared as an Applicator Training Bulletin in JPCL *in May 2002.*

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.

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.

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

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)

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 recognized methods for artificially maintaining conditions so that moisture does not condense 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 recognized 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.

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). Saltcontaminated 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 utilizes 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 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:

CMM (CFM) = Volume of enclosure x air exchanges x $^1⁄_{60}$

The $^1⁄_{60}$ 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:

Volume = π (i.e., 3.14) x radius^2 x height, or

= 3.14 x 13.5 m^2 x 12 m (3.14 x 45 ft^2 x 40 ft)

= 6,870 m^3 (254,000 ft^3)

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

CMM (CFM) = 6,870 m^3 x 4 x $^1⁄_{60}$ (254,000 ft^3 x 4 x $^1⁄_{60}$)

= 460 CMM (17,000 CFM)

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.

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/m^2/24 hours (3.0 lb/1,000 ft^2/24 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.

By Don Schnell
DRYCO

Editor's note: This article appeared in JPCL *in November 2012.*

Temperature and Humidity Monitoring for Industrial Coating Application

It has long been known that temperature and humidity have a significant impact on proper surface preparation and application of liquid-applied coatings. High humidity near the surface of dry abrasive--blasted steel increases corrosion rates and therefore causes flash rusting before the prime coat can be applied. Surface temperatures impact the rate of polymerization and the evaporation rate of solvents in the coatings as they are applied and cured. A quality coatings application can occur only when these conditions are within the tolerance of the product being applied.

To assure that these conditions are maintained, the contractor and the inspector must employ good practices to measure, monitor, and record these conditions. This attention to climatic conditions is important on interior and exterior applications and with or without climate control measures. The accuracy and completeness of this measurement and documentation not only assures a quality application, but also protects all parties from culpability should a premature coating failure occur. This article reviews good practices for measuring, monitoring, and recording ambient conditions during coating operations.

Objectives of Measuring, Monitoring, and Recording Conditions

To help ensure that the coating project is successful and that the service life of the coating is maximized, it is imperative that the conditions be monitored from the time surface preparation begins until final cure is achieved. On the industrial coating project, the facility owner should demand that regular readings be taken and recorded. To be sure that this occurs, a well-written specification must be in place and followed. The owner's representative should demand this documentation throughout the project, avoiding the disappointment of learning after the fact that the readings were not taken or documented. Any reconstruction of condition data is only supposition and a guess at best.

Current practice usually includes gathering readings for dry bulb temperature, surface temperature, relative humidity, wind speed, and dew point temperature. (See the sidebar, "Psychrometric Definitions," for more on the meaning of these different readings.) The measurement and monitoring should include at a minimum, surface temperature and dew point temperature. Although relative humidity is also important, the true relative humidity at the surface can be determined only by using the surface temperature and dew point temperature. (See the sidebar, p. 23, "Calculating Relative Humidity at the Surface.") These readings should be taken in all

PSYCHROMETRIC DEFINITIONS

Dew Point Temperature: The temperature at which moisture condenses from the air. A common example is when the air is cooled adjacent to a cold beverage and condensation forms on the outside of the glass. Dew point temperature is important on the coating job as condensation on surfaces causes flash rusting and coating cure problems. As mentioned in this article, dew point temperature is also a useful metric when determining appropriate environmental conditions.

Dry Bulb Temperature: The temperature of the air as measured by a dry thermometer. On the coating job, dry bulb temperature impacts surface temperatures, relative humidity, and material temperatures.

Relative Humidity: The moisture content of the air as a percentage of what it can hold when the air is saturated at that same temperature. When the air is saturated, it is at 100% relative humidity.

Specific Humidity: Also called the humidity ratio. This is the ratio of the actual water that is in the air to the weight of the air itself. Specific humidity is expressed in grains of water per pound of air. A grain is a simple unit of measure and there are 7,000 grains in a pound. This is another way of expressing dew point temperature.

Wet Bulb Temperature: The temperature of the air as measured by a thermometer surrounded by a wetted wick. The wick draws heat from the sensing bulb as the water evaporates. The rate of evaporation is dictated by the amount of moisture in the air, therefore, the resulting temperature indicates the amount of moisture in the air. This is only valuable on the coating job when a psychrometer is used. The wet bulb must be compared to the dry bulb temperature to determine the relative humidity or dew point temperature.

Fig. 1: Sling psychrometer Courtesy of Bacharach, Inc., and KTA-Tator, Inc.

Fig. 2: Infrared thermometer Courtesy of Raytek

areas that are in the process of surface preparation, coating application, or coating cure. The specifier and inspector also need to consider that conditions vary on different areas of the project. Here are some examples.

- Surfaces heat up when exposed to sunlight.
- Surfaces cool when exposed to the night sky, particularly on clear nights. It is typical to experience surface temperatures well below the ambient air temperature on a clear, still night.
- Surface temperatures are highly impacted by exposure to wind or air movement.
- Hot air rises.
- Buried surfaces, surfaces on the ground, and surfaces below the water line react much differently than those exposed to the atmosphere.
- Dew point temperature equalizes very quickly throughout a space. Dew point temperatures will be fairly consistent in an enclosed space unless the space is compartmentalized or elongated, or if there is excessive air flow or infiltration of outside air.

(See the Sidebar, p. 24, “Sample Specification for Environmental Conditions.”)

Manual Readings

Before the surge in electronic measurement equipment, ambient conditions were obtained in the field using a sling psychrometer (Fig. 1), and surface temperature was taken with a magnetic surface thermometer.

Infrared thermometers offer a much more convenient and accurate method for reading surface temperatures while giving the inspector the ability to get readings on surfaces several yards away from the instrument (Fig. 2).

The psychrometer is a device that holds two thermometers in an air stream. The end of one thermometer is covered with a cotton wick that is wetted with distilled water. When the air passes over the wetted wick, it is cooled by evaporation until it reaches the wet bulb temperature. By comparing the dry bulb and the wet bulb temperatures, one can determine the dew point temperature or the relative humidity using a psychrometric chart, tables, or special software designed to make these calculations. There are two common versions of the psychrometer, aspirated and sling-type. The aspirated psychrometer is housed in an enclosed case where a small fan passes the air across the wetted wick at the prescribed 600 feet per minute. The more common tool on the jobsite is the sling psychrometer, which holds the thermometers in a tube that is spun around to create the air flow. When read properly and if the water and the wick are clean, the psychrometer can be accurate within 5%, and it does not need calibration. The author prefers an aspirated psychrometer over all devices for field measurements.

A common error in reading these instruments is taking average readings or spinning the thermometers too long or not long enough. The most accurate reading is the lowest wet bulb reading the user reads. The wet bulb reading should be monitored as it drops and then begins to rise again while the wick begins to dry out, with the lowest observed reading recorded. It may take five or more tries to reach the lowest possible reading.

Magnetic surface temperature thermometers get the job done but can

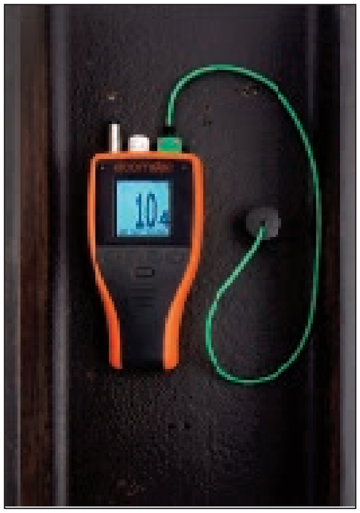

Fig. 3: Electronic dewpoint meter
Courtesy of Elcometer

Fig. 4: Electronic data logger for temperature and relative humidity
Courtesy of Onset Computer Corporation

Fig. 5: Remote monitor for checking jobsite conditions while off-site
Courtesy of DRYCO

lose accuracy with use. It is not uncommon to see these devices in use with cracked lenses, damage from falling to the floor of the tank, or paint overspray or steel grit caked on them.

Today, it is much more common to see electronic measurement instruments on the coating jobsite. These include instruments that measure dry bulb temperature, relative humidity, and surface temperature while calculating and displaying the dew point temperature. With on-board logging features, these devices are capable of logging the data collected with time stamps to later download to spread sheets or other formats. These instruments are very convenient and can allow the user to take many readings rapidly (Fig. 3). It is important to calibrate these devices regularly, particularly when exposed to extreme conditions.

Data Logging

Another approach to monitoring and recording conditions is to use some kind of electronic device that automatically takes readings and records them on paper or in digital format (Fig. 4). Simple chart recorders have been around for decades and have been used successfully on painting jobs. This mechanical technology uses a bundle of human hair or a polymer strand that expands and contracts with humidity to move a pen on a revolving disk or drum chart. Another pen will record the air temperature simultaneously. These devices must be calibrated every 6 to 12 months and are very susceptible to dust and physical damage that is quite likely on a blast cleaning and painting site. (See the sidebar, p. 24, “Calibration.”)

Electronic data loggers offer a fairly low-cost alternative to the chart recorder. Loggers add the ability to record the conditions into commonly used spreadsheet files and email the data. Typically, these loggers are very small and battery powered. The data can be downloaded to a computer with a cable link, or “shuttle” devices on some models allow the collector to capture the data in the field and upload it to a computer later. These units can be quite durable but still must be protected from the very aggressive environments typical to our industry.

Hand-held monitoring tools also have logging capabilities. Readings can be stored with a date/time stamp and the ability to download to a file for processing later. The modern hand-held electronic hygrometers also have a surface temperature sensor, which was a big step in the evolution of condition monitoring. To be able to read the surface temperature, relative humidity, and dry bulb temperature in the same location is the most accurate and meaningful way to gather this information. (See the sidebar, p. 23, “Calculating Relative Humidity at the Surface.”) It is also important to take these readings where the work is occurring. Although chart recorders and electronic data loggers can (and should) include surface temperature sensors, they are generally stationary, taking readings in one location.

Enhanced Monitoring

It is important to know if climatic conditions were not acceptable at some point during a coating project, but a completely different value is attached to being able to avoid adverse conditions. In the past decade, a significant improvement in monitoring technology has emerged. The introduction of remote monitoring allows the contractor, inspector, and owner's representative to monitor and record site conditions in real time and to see these conditions online (Fig. 5, p.22). In addition, it becomes possible to set up alarms that will contact a party when conditions deteriorate past a pre-defined point or to have an alarm go off when there is an equipment failure. These features offer the ultimate in documentation while adding the security of knowing immediately if the conditions on the project have reached a critical point.

Now, with a secure password, the interested party can check the jobsite conditions from anywhere—home, a coffee house, the office, etc.—using a laptop, tablet, or other electronic device with Internet access. When a climate control provider is used, the technician is notified when conditions are approaching the limits of the specification and can react to repair or adjust the climate control system before things become critical.

To get the most value from remote monitoring, the user should specify that the device can provide the following.

• The device should allow the user the ability to view current readings and historical data on site without the use of a laptop. The contractor or inspector should be able to walk up to the

CALCULATING RELATIVE HUMIDITY AT THE SURFACE

At 100% relative humidity, the dew point temperature equals the dry bulb temperature and condensation begins to occur. If we can keep the relative humidity (at the surface) below 50%, we can keep dry abrasive-blasted steel clean for some time. The relationship between relative humidity and surface temperature is often misunderstood and misinterpreted on the jobsite.

On the coating jobsite, the only conditions that matter are those occurring adjacent to the surface being worked on. This is an important point to make because condition readings taken elsewhere in the space can be misleading. As an example, consider a bridge project that exhibits the following conditions:

- dry bulb temperature: 70 F;
- relative humidity: 60%; and
- surface temperature: 60 F.

The observer measuring relative humidity may be satisfied that 60% is acceptable. In reality, the air at the surface of the bridge steel is cooled down to 60 F, raising the relative humidity to 85%. This condition represents a dew point temperature of 55.5 F. When compared to the surface temperature, this is a difference of only 4.5 degrees. Typical coating application guidelines call for a maximum of 85% RH and a minimum difference of 5 F between the surface temperature and the dew point temperature. This condition can easily occur at dusk on a clear night or in the morning before the sun can heat the steel.

The author has experienced many situations during tank work where panic calls come in from the jobsite regarding high humidity in the tank when the cooling equipment may be maintaining a very acceptable relative humidity at the surface. The reverse also occurs where the observer measures a nice low relative humidity in a heated tank while the cold tank surface is about to condense.

The solution is to forget about relative humidity. It changes with temperature and does nothing but confuse things. Dew point temperature will equalize in a well-contained space and is very consistent from one end of the bridge to the other. If the monitoring focuses on dew point temperature and surface temperature, we can all deal with accurate and meaningful metrics. Most measurement tools now also display dew point temperature so conversions are rarely needed.

To make the leap from relative humidity at the surface to dew point spread, a little work with a psychrometric chart tells the observer the following.

- The often-specified maximum relative humidity of 85% equates to a surface temperature that is 5 degrees above the dew point temperature.
- To preserve dry abrasive-blasted steel (often referred to as "holding the blast"), the surface temperature should be at least 20 degrees above the dew point temperature. This varies a little as temperatures fluctuate, but a 20-degree spread is a safe middle ground.

jobsite in the morning and quickly view what had occurred overnight.

• Data should be stored on the device and on the website for redundancy. This protects the data from loss due to website failure or device failure.

• Data should be available online in graph or tabular formats, with the date range sortable and downloadable into a spreadsheet or tab-delimited format at any time with the correct password.

• The system should be capable of reading and recording humidity and temperature in two locations and surface temperature in four locations.

• The data should include relative humidity, dry bulb temperature, dew point temperature, surface temperature; the difference between the dew point temperature and the surface temperatures should also be clearly displayed.

Conclusion

The methods used for measuring, monitoring, and recording the climate conditions on industrial coating projects have advanced significantly in the past decade. There are fast, accurate hand-held devices that can log the readings for later download. These instruments should be calibrated and interpreted properly to get the full value from their use. Older technologies may be less accurate and more cumbersome, but do not require calibration.

The latest technology available includes remote monitoring that meas-

SAMPLE SPECIFICATION FOR ENVIRONMENTAL CONDITIONS

3.01 ENVIRONMENTAL CONDITIONS

A. Do not apply coatings, under the following conditions, unless otherwise recommended by the coating manufacturer:

1. Under dusty conditions, unless tenting, covers, or other such protection is provided for items being coated.
2. When light on surfaces measures less than 15 foot-candles.
3. When ambient or surface temperature is less than 45 degrees Fahrenheit.
4. When relative humidity is higher than 85 percent.
5. When surface temperature is less than 5 degrees Fahrenheit above the dew point.
6. When the surface temperature exceeds the manufacturer's recommendation.
7. When ambient temperature exceeds 95 degrees Fahrenheit, unless manufacturer allows a higher temperature.

B. Provide fans, heating devices, dehumidifiers, or other means recommended by manufacturer to prevent formation of condensate or dew on surface of substrate, coating between coats, and within curing time following application of topcoat.

C. Provide adequate continuous ventilation and sufficient heating facilities to maintain minimum 45 degrees Fahrenheit for 24 hours before, during, and for 48 hours after application of topcoat.

Courtesy of Russell Spotten, Corrosion Probe

CALIBRATION

It is important that all instruments be calibrated properly and at regular intervals. This can be done by comparing the device to an electronic condensation-based hygrometer. These hygrometers use a chilled mirror to make a very accurate determination of exactly what temperature moisture begins to condense in an air sample. Quick field calibration can be done with an aspirated psychrometer. Keep in mind that the psychrometer's error margin will always be to the high side. Because the wet bulb thermometer can only cool down to the wet bulb temperature, the psychrometer cannot give a humidity reading that is too low.

ures and records conditions as well as sends them to a website where they can be viewed or downloaded in real-time. This technology also allows the users to receive alarms by email or text message when conditions on the job deteriorate.

About the Author

Don Schnell is the national strategic accounts manager for DRYCO, which is based in Downers Grove, IL. He has worked in the protective coatings industry since 1977 and has more than 20 years of experience with dehumidification and temporary climate control. He has had an important role in the development and expansion of climate-control innovations used in the protective coatings industry.

Sizing DH for Water Tank Lining Jobs

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Dehumidification Technologies, LP

Editor's note: This article appeared in JPCL *in November 2012.*

Since dehumidification (DH) was first introduced to our industry, back in the 1970s, we have been debating and wrestling with the cost of using this technology in the protective coating work for structures such as water tanks. On the first tank lining projects, over four air changes per hour were recommended, only because there was no experience with "holding the blast," and the suppliers of this new technology were trying to find a base line for a successful application. During the past 30 years, the application of climate control has matured significantly. The desiccant dehumidifier designs have advanced, and the use of refrigeration as dehumidification has become common. This article focuses on sizing DH for water tank lining projects, showing that sizing depends considerably on the goals for climate control as well as on all project conditions of the tank, from geographical location to weather conditions and project specifications.

Photo courtesy of the author

Technical Tip 1:

What is the difference between a desiccant and a refrigeration type dehumidifier? In a desiccant unit, the air is passed over a desiccant, such as silica gel, that attracts the moisture from the air. The desiccant is then rotated through a heater chamber that regenerates the material so it can attract more moisture. A refrigeration type dehumidifier is different in that the air is passed over chilled coils where the temperature is lowered below the dew point temperature. This causes the moisture in the air to condense on the cooling coils and is then drained away. In a desiccant unit, the air is discharged at a lower dew point but higher temperature, while a refrigerant dehumidifier discharges air at a lower dew point and a lower temperature.

Technical Tip 2:

The air adjacent to the surface in the tank is virtually the same temperature as the surface. As an example, in air that is 75 F and 30% RH, the RH will increase to 72% near a surface that is 50 F.

Safety Tip:

Although common sense would tell us to re-circulate conditioned air back through climate control equipment to save energy and increase performance, re-circulation can create some serious hazards. Without introducing fresh air into the tank, solvents and fine dust particles will build up, causing hazardous and even explosive environments. Also, re-circulating solvent vapors or dust-laden air can destroy components in dehumidifiers, such as very expensive desiccant rotors. Never re-circulate air through climate control equipment during coating application.

Goals for Climate Control

The first step in determining the right equipment (See Technical Tip 1) is to understand the goals for climate control. These are a few basic and typical goals.

1.Preserving the blast-cleaned surface until the primer or coating is applied
2. Maintaining surface temperatures for coating application and cure
3. Providing worker comfort

If a goal is to preserve the blast-cleaned surface, we know that it will be necessary to maintain the relative humidity (RH) below 50% at the surface. Research has told us that corrosion rates increase dramatically when the RH climbs above 50%. Since it changes with temperature, RH is strongly impacted by the surface temperature (See Technical Tip 2).

RH at the surface can also be expressed as a difference between the surface temperature and the dew point (temperature at which moisture condenses on steel) in the space. On a psychrometric chart, it can be shown that when the surface temperature is 17-20 degrees above the dew point, the RH at that surface will be around 50%. This is why it is often recommended that the dew point temperature be kept below a point that is at 15, or sometimes 20, degrees below the surface temperature to preserve the blasted surfaces. (The often-heard 5 degrees below the dew point is a minimum required to avoid actual condensation.)

Maybe you have determined that surface temperatures will be too low for the specified coating to be applied or cured. The most common solution to this problem is to heat the air inside the tank. In simplest terms, the steel temperature will be between the inside and the outside temperature. As the wind removes the insulating layer of air from the outside surface, the steel is further cooled by the outside air. In the same way, air movement on the inside removes the insulating layer of air and allows the steel to be warmed by the heated air in the tank. On a cool, clear night, radiational cooling also works against efforts to heat the tank. The steel surfaces, particularly on the roof, lose additional heat to the atmosphere, just as does the roof of your Tahoe or Taurus.

It is possible to calculate the expected surface temperature of a tank using a very complex formula that considers surface area, inside and outside temperatures, inside and outside wind speed, and the radiational cooling. Heater suppliers use spread sheets to calculate these heat losses. The result is in BTUs per hour of heat lost through all the surfaces of the tank. Heaters are measured in BTUs, and the heat loss in BTUs is the primary factor needed to determine how big the heater must be. The airflow through the heater must also be considered because BTUs are lost as the air exits the tank on the other side. (See Safety Tip.)

If worker comfort is important, we must consider surface temperature and air temperature. At elevated temperatures, workers must take more frequent breaks, which is a big drain on productivity. This goal can be helped or hindered by other objectives for climate control. For example, in Thief River Falls, Minnesota, it may require 110 F air temperature to main-

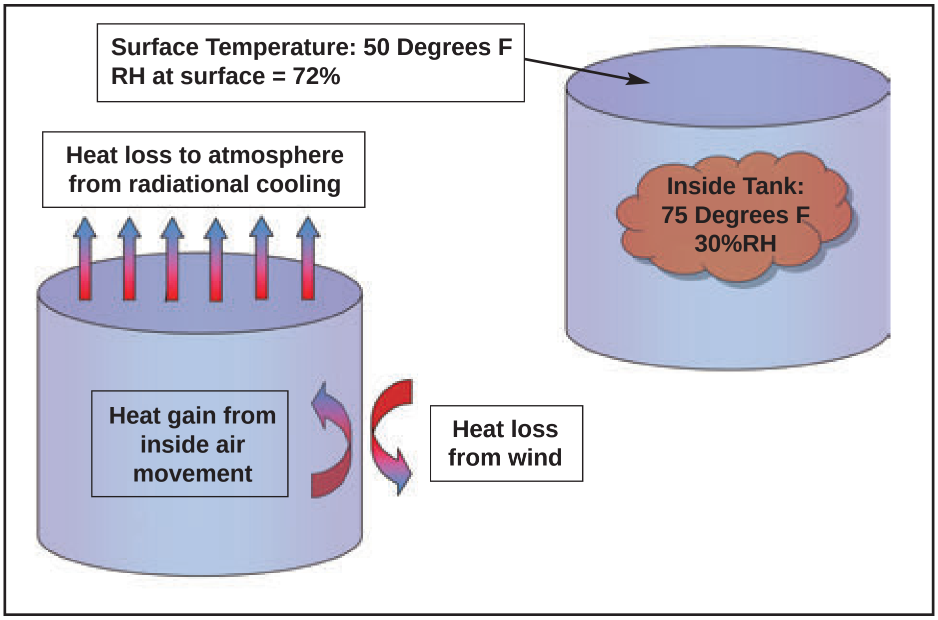

Fig. 1: Factors that affect surface temperature
Courtesy of the author

Technical Tip 3:

Air changes are calculated as (interior volume X required air)/60 min. = DH capacity in cubic feet per min. (cfm).

tain a 50 F surface temp. But 110 F creates a very hostile work environment. In this case, insulation may be necessary to lower the heat required, or a more temperature-tolerant coating may be needed, as long as the owner agrees to the change. In Tupelo, Mississippi, where average summer high temperatures are over 90 F, a DH system that includes some cooling is more efficient and more comfortable.

Know Your Project Conditions to Calculate Your DH Needs

The amount and type of dehumidification required is affected by project conditions and weather conditions. Understanding project conditions requires addressing the following:

•Is the applicator attempting to preserve the cleaned surface and for how long?
•Is the tank steel or concrete?
•How many openings does the tank have or is it well sealed?
•Is the tank insulated, contained, or in a building?
•What conditions are required for coating application and cure?
•Are there other sources of ventilation such as dust collection?

Understanding weather conditions requires addressing the following:

•What are the expected dry bulb (air) and dew point temperatures?
•What is the expected wind speed?
•What are the expected high and low temperatures?

In today's industrial coating work, we often find DH recommendations based on loose and general rules of thumb. These "rules" are often based on standard equipment and the number of air changes that the unit will supply per hour in a tank or space. An "air change" is when the volume of air in a tank is completely displaced by the ventilation system. The "rules" are also all too often drawn from limited experience (sometimes, very limited experience) or assumptions about what might be considered typical conditions.

The volume of air in a cylindrical shape is calculated as follows: radius X radius X π X height. (See Technical Tip 3, p. 28.)

Expertise is needed to determine the number of required air changes per hour. With the advances in the technology, it becomes more advantageous to spend the extra effort to understand the project and to be sure that the best technology and the best equipment are used. The pay-off for this effort should be cost savings, fuel savings, improved reliability, and shortened work schedules.

Consider the most common rule of thumb: two air changes per hour. This recommendation is solid if you are using desiccant units in a one-million-gallon tank in Topeka, Kansas, in May, when the average temperature is around 65 F. Experienced dehumidification people know that we can preserve the blast-cleaned surface well in this scenario. Otherwise stated, "the dew point temperature in the tank will be lower than 15 degrees below the surface temperature" or "the RH will be lower than 50% at the surface."

Move this same one-million-gallon tank to Tampa, Florida, with 90 F highs and a 75 F dew point temperature, and refrigeration DH at four air changes per hour might be more appropriate. But be careful: you might not be able to hold the blast very long. A little-understood fact is that refrigeration dehumidification loses its effectiveness as temperatures drop below 65 F. This can be illustrated by starting with the expected surface temperature and remembering the all-important 15-degree F spread between the dew point and surface temperature. Let's start with the assumption that the surface temperature equals the ambient air temperature—65 F. To preserve the blast, the dew point in the tank must be 15 degrees F lower, or 50 F. For a cooling unit to accomplish this, it should be delivering air colder than 40 F to overcome infiltration and other moisture loads. For a cooling unit to deliver air at 40 F, the coils themselves will be approaching freezing temperatures. Although there have been significant innovations to defrost cooling coils, they all begin to lose effectiveness as ice builds up on the coils.

To further complicate things, on a clear night, roof temperatures can reach low temperatures almost 10 degrees below the ambient temperature. Another important consideration is that the typical refrigeration dehumidifier in the industry has a fixed process air blower, meaning that it delivers a specific fixed air volume. A refrigeration unit's ability to lower the dew point temperature is in proportion to the speed at which the air passes over the cooling coil. At the typical air speed, the unit may be capable of lowering the dew point temperature only a few degrees, and the blast may turn because you cannot maintain that all-important 50% relative humidity at the surface.

If you intend to preserve the blast with refrigeration DH, it is also important to re-heat the air after cooling it. This sounds like a waste of energy but by re-heating the air after it has been cooled to lower the dew point temperature, you are raising the RH where it enters the tank. Also, by re-heating, you avoid cooling the surface temper-

Technical Tip 4:

Why does it take fewer air changes per hour to control a large tank? A dehumidifier's ability to control conditions in a tank is affected by the amount of infiltration of ambient air and internal moisture sources. This determination is largely a function of the ratio of the volume of the space to the area of the openings in the tank. To illustrate, consider a 100,000 gallon tank with two 30-inch manholes and a one-million gallon tank with two 36-inch manholes. The ratio of volume to the openings in the small tank is 1,365 cubic feet/square foot of opening where that ratio is 9,469/1 in the one-million gallon tank. There is seven times the infiltration potential on the smaller tank.

atures at night and losing that 15-degree dew point spread.

Combining refrigeration with pre-cooled desiccant dehumidification presents a very effective solution in warmer climates, and you might be well served with less than one air change per hour. This combination allows the operator to get the aggressive dew point control of the desiccant unit and the benefit of cooler air during the day. In more humid environments, the cooling unit removes a lot of the moisture, and by feeding the desiccant unit with that drier, cool air, its performance is also improved.

On a five-million-gallon water tank in Troy, New York, two air changes are probably a big waste of taxpayer money. With this large volume space (670,000 cubic feet), the air is stabilized and not as affected by infiltration. Don't try to use refrigeration on this job. No amount of cooling will preserve your blast when the surface temperature is 40 F.

The exact amount of dehumidified air can be calculated if the weather conditions are known and we can quantify every infiltration source and every internal load on the job. In reality, it is not practical to perform this in-depth engineering exercise on each tank, and in fact, we cannot predict all of these loads accurately. Air flow, compressor capacity, and infiltration are all subject to change by the day and hour. In addition, if the calculation called for 2,853 cfm with a desiccant unit, the equipment supplied would be rounded up to a commercially available 3,000 or 3,500 cfm machine. This is why most recommendations are based on experience, aided by weather data and site conditions. The more experience…the better the recommendation. (See Technical Tip 4.)

There is a misconception that the dehumidification volume must match the dust collector, cfm for cfm. Depending on your choice of DH system, you may be able to allow large amounts of ambient air to mix with the DH and still maintain the proper conditions. Again, what works in Toledo, Ohio, may not work in Tulsa, Oklahoma.

Have you ever been to Towner, North Dakota? The average winter temperature is about 15 F. If you heat the surface up to 40 F for coating, it will be 25-30 degrees above the dew point temperature. In effect, you are creating the same dew point spread as would a dehumidifier. You might want to think about insulating this tank. Without insulation, you will need over 110 F inside to maintain that surface temperature at 40 F.

The other extreme is when the surface temperature is very high. In Tucson, Arizona, a pre-primed tank may not require a wide dew point spread because you may not be holding the blast. Your objective may be to control condensation and provide a habitable work environment. Traditional refrigeration may be a great choice. Don't let the desert weather fool you. A dew point of 65 F is not uncommon in the summer months. Even if you are holding the blast, your requirements change when you are all primed out and just coating.

What about a concrete tank in Tehachapi, California? You might need to remove the excess moisture from the concrete. If this is your goal, you will need to be very aggressive with the dew point spread. This will create an extreme difference between the moisture content in the concrete and the moisture content in the adjacent air, causing the moisture to quickly migrate from the concrete. Heat can also be helpful. There are a lot of dynamics in play here as we deal with vapor barriers, buried surfaces, efflorescence, out-gassing, and porosity. If your only issue is to keep a dry substrate, just make sure the surface is five degrees above the dew point temperature. Again, there is no simple formula, but the good news is that you don't need to worry about holding the blast in a concrete tank.

What about Costs?

This conversation would not be complete without some discussion around costs. The sad fact is that much of the focus comes down to rental rates when even the most drastic discount on rates is quickly overshadowed by the right choices of equipment, energy sources, and even delivery options. All energy sources should be explored carefully. By finding line power on a recent project, the customer was able to save over 33% of the entire cost of the climate control. Even after some expensive electrical work and paying for the electricity, the contractor was able to reduce these costs by eliminating a portable rental generator and the expensive diesel fuel to run it.

Conclusion

Unfortunately, sizing climate control is not as simple as calculating spread rates on an epoxy coating or abrasive consumption rates. By considering all of the parameters and all of the available technologies, large sums of money can be saved. Sizing DH may not be rocket science, but it is a science. Very different rules apply in Biloxi, Mississippi, than in Bellingham, Washington.

About the Author

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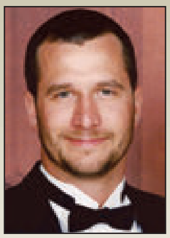
Editor's note: This article appeared as a Problem Solving Forum in JPCL *in September 2009.*



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How to Set Up Ventilation in Confined Spaces

How do you set up ventilation equipment for worker protection where access is difficult, such as manholes?

Proper ventilation of a confined space, such as a manhole, is a critical component of any Confined Space Entry Program. Almost all manholes, whether they be for sewer, telecommunications, water, or gas services, fit the definition of a permit-required confined space, as defined by the Occupational Safety and Health Administration (see 29 CFR 1910.146 and 1910.268(o)(2)). When fatal confined space accidents occur, more than one element of the safety system has typically failed, including, most often, the accurate monitoring of the atmosphere. OSHA estimates that 85% of permit space accidents would be eliminated by entry personnel reviewing atmospheric testing before entry. While these tests and controls are critical, there are many other possible hazards in a confined space. Ventilation requirements hinge on accurate monitoring.

Once the atmospheric hazards of a space have been identified through testing and site evaluation, the next step is to implement controls, such as isolation and ventilation, to mitigate the hazards. Isolation can be accomplished in manholes by blocking or plugging entry points of toxic, flammable, or oxygen depleting/displacing gases. However, in some situations, not all hazard sources can be blocked, and proper ventilation is thus critical. The following are some key points to ventilating manholes.

• Ventilation equipment must be properly sized

Properly sizing manhole ventilation equipment is a fairly simple process.

The average manhole, at 4 ft (1.2 m) diameter x 10 ft (3 m) depth, contains only about 125 ft^3 of atmosphere. A standard portable blower produces about 600 CFM of air at the end of a 15 ft (4.5 m) x 8 in. (0.2 m) duct. Using this equipment effectively changes the atmosphere in such a manhole over 200 times per hour, greatly exceeding the minimum recommendation of twenty.

Additionally, it is recommended to allow at least seven air changes to sufficiently purge a structure, which in this case would take about two minutes. When dealing with large structures, the calculations become more critical but most portable ventilation equipment is suitable for manholes less than 15 ft (4.5 m) deep.

• Ventilation must draw from a source of safe supply air

Ensuring a clean air source is as important as providing sufficient airflow. Using positive pressure from a clean source is the best way to ensure that fresh air is distributed into the space. Entry points and blower locations must be examined for sources of hazards to avoid introducing the hazards into the atmosphere inside the structure. Many manholes are located near vehicular traffic that can produce large amounts of carbon monoxide, so a blower should be positioned away from traffic flow and idling vehicles. A common practice in the sewer industry is to place a negative pressure ventilator on an adjacent manhole and draw air through the pipeline and entry manhole. While this practice can produce effective airflow, this method does not isolate the structure from hazards that can be drawn in from connecting pipelines. OSHA's published position is that the required continuous forced-air ventilation specified in 29 CFR 1910.146 paragraph (c)(5)(i)(B) means a delivery system or device that provides positive pressure for the space where the employees are working (typically requiring a blower at the manhole entrance).

• Effective ventilation of the entire structure must be verified

Verification of adequate ventilation is accomplished by rechecking the structure's atmosphere following the initial purge time. It is critical to check each area of the structure to ensure that effective air changes are occurring in all accessible spaces. Using extended pick-up tubes or hoses and the necessary electric or manual air pump(s), start from the top of the manhole and perform a check every five vertical feet all the way down to the floor or invert. Always allow time for the pump to pull the air sample from the end of the tube/hose to the test device before moving on to the next test location. Many toxic and oxygen-displacing gases are heavier than air and can accumulate at the bottom of a manhole, even if fresh air is being introduced at the entry point. Blower ducts should be inserted to a depth that ensures delivery of fresh air to the lowest point. Also, irregular spaces within a manhole may require special ducting or additional blowers to distribute fresh air to adjoining spaces (never use a blower within a confined space unless it is rated for hazardous locations).

• Ventilation must be maintained at all times

Ventilation should always be maintained while the structure is accessible.

While this is good common practice, it is also required when there is the possibility of an atmospheric hazard. Once in place, a ventilation system should never be turned off or removed until all entrants have exited the space and the entry point is secured.

Of course, there are many other issues when dealing with entry into manholes. Employers and workers need to be aware of the hazards, how to test for them, and how to safely and effectively mitigate them. Ventilation is a key component of any safety program and should not be undervalued, even when dealing with relatively simple structures like manholes. Check with your local safety equipment supplier for recommendations that suit your needs and meet the criteria to provide a safe work environment. Ultimately, ventilation of confined spaces should be a component of a comprehensive Confined Space Entry Program, which is required by federal law for any employer who exposes personnel to confined spaces that meet the criteria set forth by OSHA.

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There are a number of different ways to ventilate areas that are difficult to access. Options for ventilation are air horns, dust collectors, air conditioners, coppus blowers, and dehumidification equipment. Along the Gulf Coast, we commonly use dehumidification equipment to perform this function, as well as help with corrosion control.

The question presented brings to mind a situation of working on the interior of a small tank or vessel. In this situation, forced ventilation (via flexible trunking) should be used. Assuming the tank being worked on has only two manways, we would set up the ventilation equipment to have one access for worker entry and use the other access for running the trunking through. The manway used for the trunking would then be completely sealed. The trunking should be arranged so that air moves continuously in all areas and no dead air spaces exist. Please note that whether you are in the process of blasting or painting, the ventilation must be arranged so as not to reintroduce abrasive dust and solvent vapor into tanks; consult with the equipment supplier for directions on placement of ventilation equipment.

In a situation where there is only one manway on the tank or vessel, we would use the manway for worker access and run all duct/hoses through any piping where flanges have been dropped and the diameter of piping is large enough to allow access for ductwork.

With either one or two manways, air should be changed often enough to properly protect workers (depending on the activity they are performing—e.g., blasting or painting). To do this, calculate the volume of the area being worked on and then decide, depending on the project, how many air changes per hour are needed to be safe, and obtain the production needed for each individual activity of the project. We utilize the product MSDS for ventilation recommendations and guidance, along with equipment suppliers' recommendations for number of air changes per hour.

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Brendan Fitzsimons, Pyeroy Group Ltd.

The process of working in a confined space is complex, and extreme caution must be taken before the task is undertaken. A risk assessment of the task is essential and must be conducted by a competent person. The aspects of a confined space job that the risk assessment should look at include the process of work; the type of work to be conducted; the location, tools and materials used; the duration of works; and COSHH (Control of Substances Hazardous to Health) assessments. Once the information is compiled, the risk to the workers has to be evaluated and a proper risk plan and method statement produced, all of which must be fully understood by the workers.

The area and volume of the confined space must be calculated and a ventilation plan developed, along with an emergency evacuation plan and ways of monitoring the process.

The ventilation plan should consider the cubic area of the location and the location and size of the access or manhole. The supplier of the equipment should indicate the relevant extraction capacity of the equipment, taking into consideration the size of the area and the ducting size and length. The concentration of dusts or fumes created (i.e., volume of paints/solvents used in area/time) can be also calculated and taken into account. The information can be tabulated so that monitoring can be conducted on a continuous basis. The monitoring is generally done manually.

Worker training is essential for tasks such as surface preparation and coating application; training is also essential for working in confined areas. Workers rely on the management and supervision to have "done their homework" for them in advance of the job.

The equipment supplier should be able to advise for the full specification of the equipment used and the power requirements. (The user, however, must consider how this fits in with the work patterns/shifts.) The hose length and size are also important to ensure adequate fresh air is supplied, and when calculating the number of air changes per minute, remember this is based on a "non-obstacle" basis (i.e., the space is free of anything that could impede the easy flow of air).

A plot plan demonstrating the size of equipment in cubic feet per minute and required air changes per minute is useful. In critical contracts, it is worth setting up a two-part demo process off the jobsite: one part before site installation without obstacles, and the second part a live set-up with obstacles. Dust or fumes can be monitored by in situ equipment or attached to working personnel.

The quality of ducting can vary, so it is important to purchase it from a recognized source. Holes and damage of even a few inches can make dramatic changes to air movement. The same can be said for bends.

Confined spaces should have two means of escape, and the means of access should never be blocked unless the obstacle is easy to remove instantly. The extraction equipment has to be working correctly and placed in the correct location (usually lower sections of an area).

There is no doubt that most of the work must be conducted at supervisory and management level well before the task is conducted. Having the correct procedures in place will ensure potential problems are dealt with in advance.

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