DEHUMIDIFICATION AND OTHER ENVIRONMENTAL CONTROLS FOR COATING PROJECTS

A **JPCL** eBook

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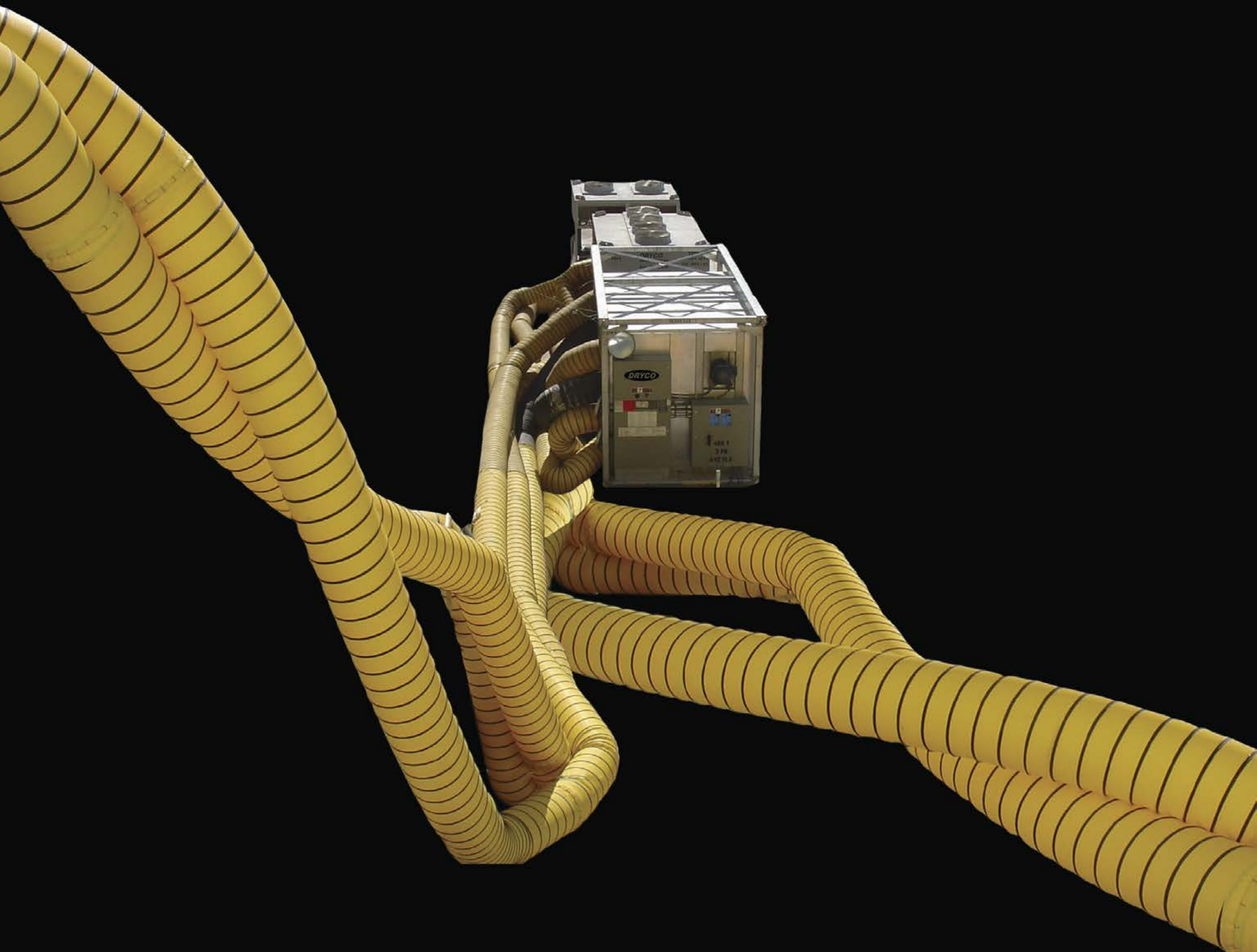
Contents



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

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The Basics of Dehumidification

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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.

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

Absolute and Relative Humidity

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

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

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

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)

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:

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

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

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

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

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

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

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 $15 g/m^2/24$ 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

Dehumidification equipment set up for painting operations inside three tanks 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. JPCL

By Don Schnell,
Dehumidification Technologies, LP

Sizing DH for Water Tank Lining Jobs

Editor's note: This article appeared in JPCL *in May 2011.*

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.

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.)

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.

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.)

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.

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 maintain 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.

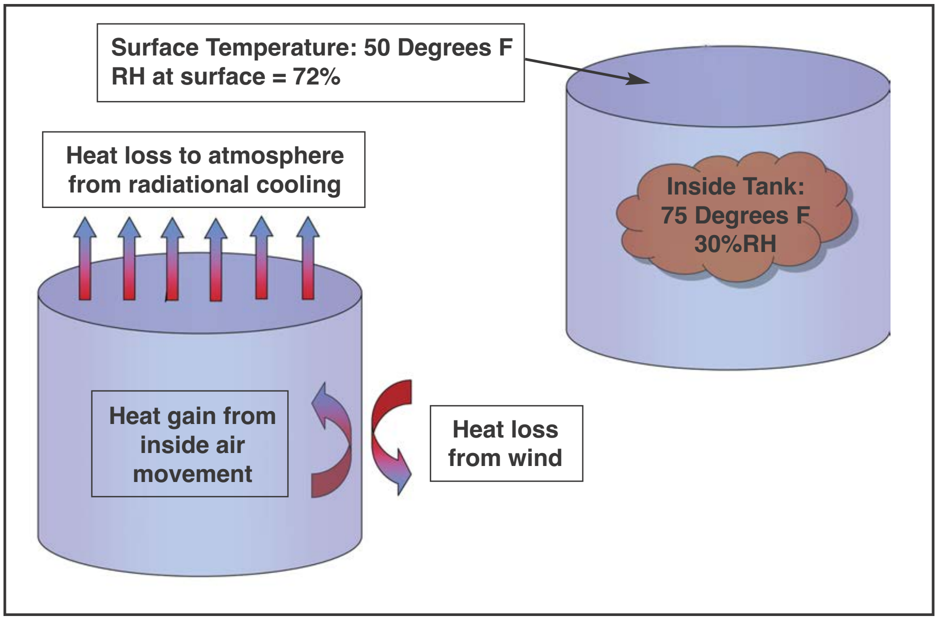

Fig. 1: Factors that affect surface temperature
Courtesy of the author

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.)

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.

Technical Tip 3:

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

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 reheat 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 temperatures 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

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.

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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JPCL

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Protecting Ships with DH During Long-Term Lay-Ups

Editor's note: This article appeared in JPCL *in March 2010, and is based on a paper presented at PACE 2010, the joint conference of SSPC: The Society for Protective Coatings and the Painting and Decorating Contractors of America, held February 7–10, 2010, in Phoenix, AZ.*

Here's an approach to reducing painting and other maintenance costs on ships in lay-up.

Since mid-2008, oceangoing freight companies have felt the pinch of the worldwide recession with a dramatic decline in orders for transport. The decline has affected almost every type of vessel, including oil tankers, cargo vessels, cruise ships, and even luxury yachts. It is estimated that over 1,000 ships are in either hot or cold storage all over the world, and about half of these are container vessels while 200 are bulkers. Additionally, many cargo ships are leaving port at 50% to 70% capacity, which negatively affects the profitability of their trips. Recently, low demand in crude oil left many oil tankers at sea with no apparent destination. The shipping industry is in a crisis.

Given the recession and the enormous operating costs of ships, laying up underutilized vessels and running fewer vessels with higher loadings to maximize profit per sailing often makes more economic sense. Therefore, it was no surprise to see an increasing number of ships being laid up in 2009. With the increase, cost-effective, corrosion-prevention strategies for long-term cold lay-ups are essential.

This article will discuss the use of temporary desiccant dehumidification and climate control equipment as a strategy to prevent corrosion and other damage to ballast tanks, electronic systems, engine rooms, and other parts of a ship during cold lay-up, thereby reducing maintenance painting and other costs and protecting one's investment in a ship. The article will look at the science of psychrometrics and discuss how its use can help predict the optimal conditions to effectively control moisture in a ship indefinitely. The article will also discuss the corrosion cell and how it can be manipulated with climate control technologies. Finally, the article will compare different types of climate control methods used for mothball applications and make recommendations for what technologies are best for certain seasons.

Why Lay-Up?

The laying up of a vessel makes sense when consumer demand is low. Low demand will reduce the profit for the owner and will eventually create a financial burden. Often, laying up the vessel provides a solid business case by reducing excessive deterioration (and subsequent repair) of the ship's mechanical and electrical systems. Additionally, only a small crew is required to maintain a laid-up ship, thus reducing overall costs to the owner. Other benefits include reduced costs for fuel, oil, maintenance, equipment replacement, and insurance.

Typically two types of lay-up procedures are used: hot and cold. This article will define both processes but will concentrate primarily on the cold lay-up process, in which, compared to hot lay-up, ships are more affected by the destructive nature of long-term moisture infiltration.

Hot Lay-Ups

In hot lay-ups, the machinery is kept in operation for the sake of fast re-commissioning. However, measures are still taken into consideration to lower the overall operational costs, including reducing crew size or eliminating some mechanical operations such as heating and ventilation systems. The length of time that the vessel is laid up will determine the required restart protocol. For example, a ship that has been laid up for 1 month would require a 24-hour restart procedure.

Cold Lay-Ups

In cold lay-ups, the machinery is taken out of service, and the vessel is kept electrically dead, except for its emergency power. This condition usually implies a three-week re-commissioning time or more depending on the preservation and maintenance during lay-up. Minimum manning covering fire, leakage, moorings, and security watches should be kept. The lay-up site is usually in a remote area and access is limited. Power is kept to a minimum but is sufficient to ensure that emergency equipment and other essential systems, such as navigation lighting, winches, and mooring equipment, are operable. Re-commissioning after an extensive lay-up period (over 5 years) might require more than 30 days.

The cold lay-up process is an arduous task, with an extensive checklist of procedures. The procedures are intended to ensure that the preservation of the vessel is done in the most cost-efficient way possible. The lay-up site is usually well-sheltered from heavy winds, strong currents, and swells. It should not be in tropical cyclone areas, and the seabed characteristics should be able to provide adequate anchoring. In most cases, the vessel will be kept in "blacked out" mode with minimal crew on board and power being supplied to essential equipment from a portable generator placed on deck. All of this careful planning is done in anticipation for the day when the ship is called back to duty so that it can be brought up and running in the shortest possible time without the need for major repair caused by corrosion, mold, or material rot.

Fig. 1: Ship's engine room
Figs. 1, 2, 4-10 courtesy of Munters Corp.

Challenges during Cold Lay-Up

There are many challenges to protecting a ship during a long-term lay-up, including vandalism, natural disasters, and general deterioration. However, the biggest threat to the well being of a vessel in cold storage might come from the abundance of moisture at sea. Continuous high levels of moisture (relative humidity) can provide the catalyst to corrosion on these vessels, which are made up primarily of steel. During re-commissioning, corrosion can create havoc by causing motor and drive trains to seize up, which results in costly and potentially long-term repairs. Additionally, excess corrosion can severely damage the onboard computers and navigational equipment inside the control rooms. Whereas body panels can be replaced relatively easily, the brains and heart of the ship, such as the navigation electronics and engine components, are not as easily replaced (Fig. 1).

Mold can also create costly remediation efforts due to these long-term lay-ups. Typically, where there is moisture and an organic food source such as dirt in unprotected areas, there is mold. Mold can damage materials on the ship and create health risks for the crew when the ship returns to service. Additionally, excess moisture can lead to the rotting of materials on board. Again, the replacement of these items will be costly and may lengthen the amount of time required to re-commission the ship. When the ship is ready to return to normal trade, dry preservation is recommended, and all preservation actions should be carefully documented.

The Corrosion Cell Simplified

So moisture presents a major challenge for protecting a vessel at sea. How does moisture affect the corrosion process and what can be done to predict its onset?

Corrosion is an electrochemical reaction. The typical corrosion cell consists of an electrolyte as well as a cathode and an anode (which steel contains and helps conduct electricity for the reaction). Corrosion occurs only when all three parts are present. Moisture is the electrolyte that provides the conduit for the reaction to occur. If any of the three parts of the cell can be controlled, corrosion growth will be limited but will never stop unless a structure or component is in a vacuum. The rate of corrosion depends on the amount of moisture present. For example, relative humidity—the percentage of moisture that air can hold at a specific temperature—will lead to less corrosion at levels below 50% than at 70%. Relative humidity above 50% creates conditions that accelerate corrosion exponentially, leading to flash rusting. As such, the key to corrosion control is to control the moisture level or relative humidity (Fig. 2).

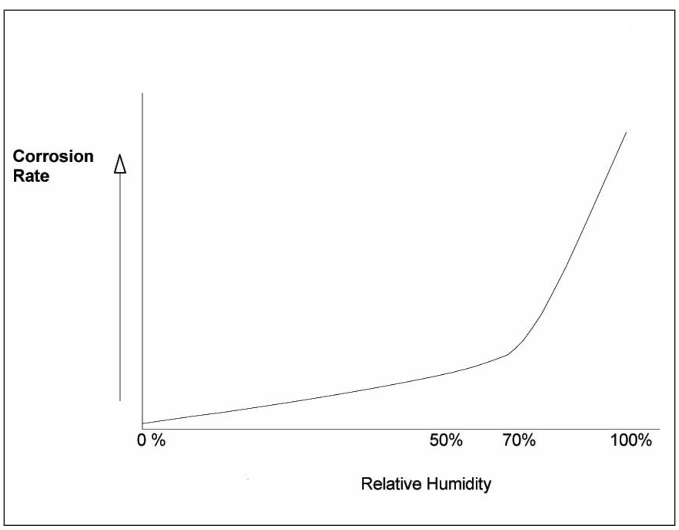

Fig. 2: Corrosion rates vs. relative humidity

Moisture Analysis: The Science of Psychrometrics

To understand how moisture might affect the steel, it is important to understand psychrometrics, the science of moisture in air. Psychrometrics is relied on heavily when engineering a moisture-control method. Psychrometrics can predict, with certainty, the ambient conditions that will provide the greatest chance of corrosion occurring on the vessel. The psychrometric chart has eight indices to measure the moisture levels within the air. Dew point temperature, relative humidity, dry bulb temperature, and wet bulb temperature are the most commonly used indices when calculating moisture levels in a space. By knowing any two of the eight variables on the psychrometric chart (Fig. 3, next page), you can calculate any of the other values. For example, by knowing the relative humidity and the dry bulb temperature, you can easily find the dew point temperature or vapor pressure.

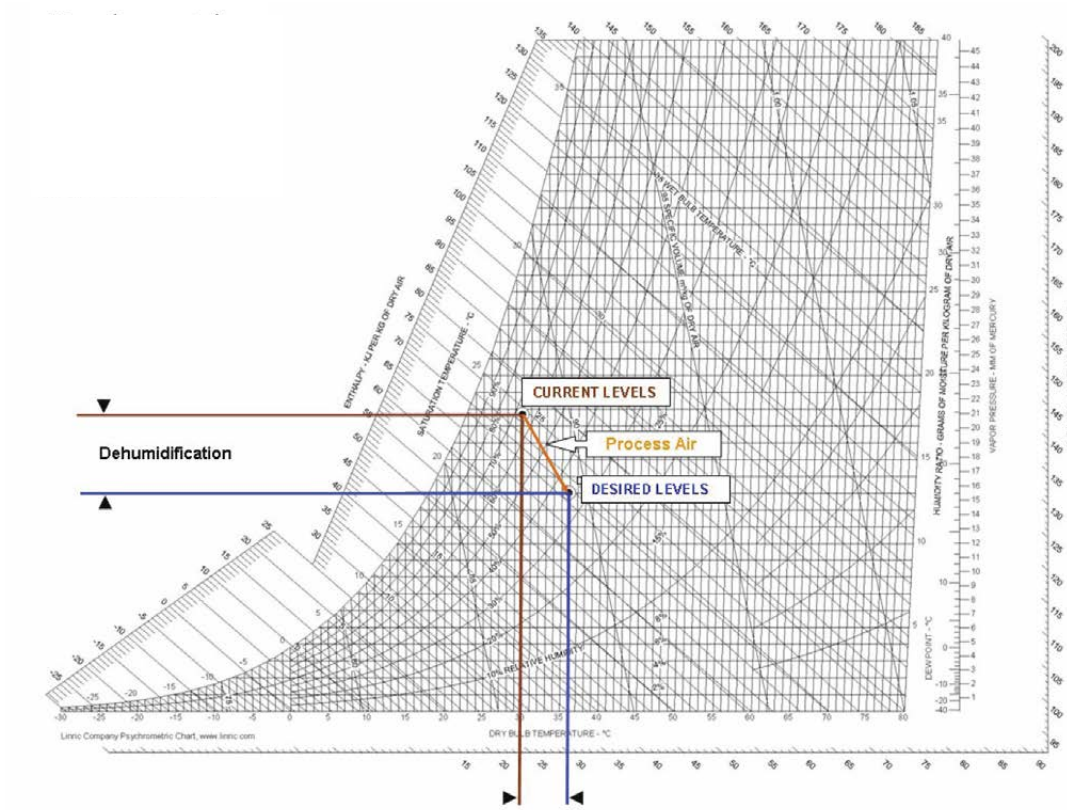

Fig. 3: The psychrometric chart (IP version) can map out moisture changes from the air
From www.linric.com

The use of psychrometrics allows ship owners to make critical decisions about the best time to install the temporary climate control equipment and to determine the type and quantity of equipment needed to safely protect their ships. Correct sizing is vital to ensure that a ship owner gets the exact conditions demanded from the specifications so that costs are not incurred for unnecessary equipment and fuel. Psychrometrics is the tool that ensures that the moisture is managed and thus will keep the corrosion cell in check as much as possible.

The Concept

The general concept behind the use of temporary dehumidification or climate control equipment to lay up a ship is to create an environment that reduces the relative humidity in the space below 50%. The conditioning process should create a differential between the dew point temperature in the space and the temperature of the actual surface. If the surface temperature reaches the interior dew point temperature, moisture vapor from the air will condense on the surface. The steel surface will then be at risk for corrosion. In the control rooms, excess moisture can corrode electronic components, resulting in short-outs when restarted.

As noted above, mold can also grow in these confined areas, creating remediation concerns. Often, typical air conditioners providing cool air cannot create effective conditions to ensure that condensation will not form.

Dehumidification equipment is fundamental to bringing air in the enclosed areas of the ship, such as ballast tanks, storage tanks, and control rooms, to a relative humidity not exceeding 50%.

Dehumidifiers

Dehumidification is the process by which moisture is removed from the air. There are primarily two methods of dehumidification:

- Refrigerant—Removing moisture by passing wet air over a refrigerated coil
- Desiccant—Using substances that attract moisture (desiccants) to remove the moisture by vapor pressure differential

Fig. 4: Refrigerant dehumidifier

Refrigerant Dehumidification

Refrigerant dehumidification is an effective way to remove moisture from the air in small, confined spaces (Fig. 4). With refrigerant dehumidification, moist air is passed directly over refrigeration coils and cooled below the dew point; the moisture condenses from the air. The air comes off the coil saturated and must be reheated to lower the relative humidity. It is then pushed into the space. This type of unit typically can provide a relative humidity range of 15% to 20%. Additionally, most refrigeration units are too small to condition large areas and are limited in their ability to significantly change dew point in a space. They can be used effectively in control rooms and living quarters, especially to reduce the threat of mold.

Fig. 5: Desiccant dehumidifier

Desiccant Dehumidification

Desiccant dehumidification is the workhorse for moisture removal from the air in large spaces (Fig. 5). Desiccants attract moisture from the air by creating an area of low vapor pressure at the surface of the desiccant. The pressure exerted by the water in the air is higher, so the water molecules move from the air to the desiccant, and the air is dehumidified. In one type of dehumidifier, as the process air passes through what is called the desiccant wheel, moisture is absorbed and trapped. As the wet wheel rotates, it is dried out by heated reactivation air (Fig. 6). Once the wheel is dried, it is ready to absorb more moisture. Desiccants in this application are based on silica gel, which is ideal for highly saturated air streams. The desiccants have very good moisture removal capacity over a broad range of humidity levels. Because desiccant dehumidifiers are available in large capacities, they are the most appropriate for use in lay-ups. Depending on the time of year of the lay-up, different measures should be taken to control the temperatures in the vessel. For example, an air conditioning package can be combined with the desiccant to optimize the controlled climate if there is a need to work in the space in warmer climates.

Power is always an issue on a ship that has been laid-up. Often, the dehumidification equipment has to share the same generators that provide power to all the other onboard utilities (such as fire suppression systems). The units selected will have to be energy efficient to reduce the overall running costs of the vessel during the lay-up period. Also, the equipment selected must be extremely reliable to minimize unplanned downtime.

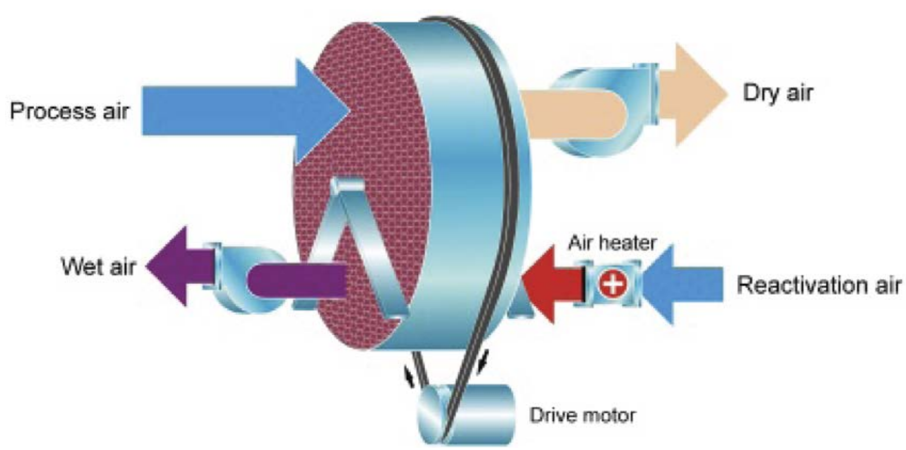

Fig. 6: Desiccant dehumidifier wheel assembly

Designed Dehumidification Systems

Dehumidifiers can be placed inside the controlled space, or they can be placed on the deck outside, with temporary ducting used to move the air into the protected areas.

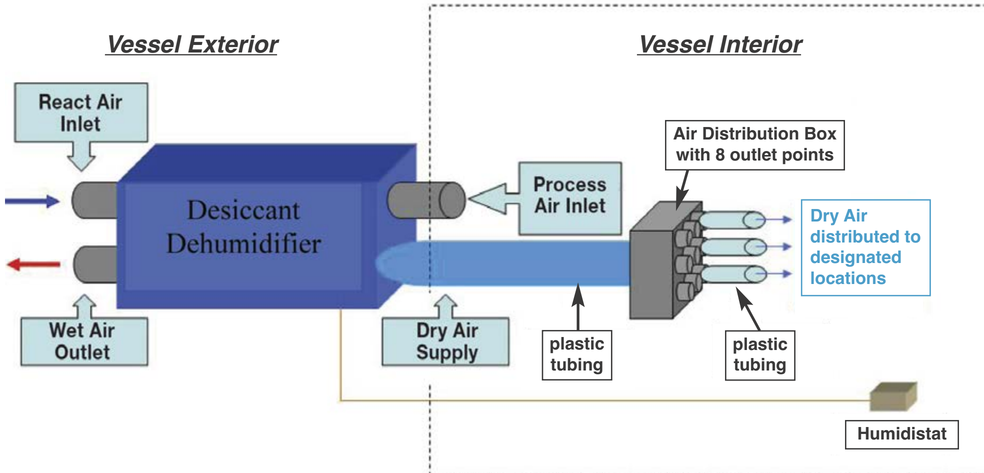

Fig. 7: Closed Dehumidification System

Often, refrigerant units are placed directly in the smaller spaces to be controlled, and the condensate is disposed of through a hose to a nearby drain. The desiccant units are extremely large and often cannot be placed in the space that is being controlled.

Closed Loop Dehumidification System

Closed loop system dehumidification is used where the enclosed air volume is re-circulated through the dehumidifier (Figs. 7 and 8). Often the moisture load outside is so great that re-circulation is the only viable way to create a cost-effective dehumidification system. A closed system works most efficiently when all openings in the space are sealed to minimize air infiltration from the outside. Air from inside the space is returned to the dehumidifier to be dried again. The reprocessed air is then redistributed to the space through an air distribution manifold. Due to this continual drying process, the air is extremely dry (<1% RH). The manifold should be placed in the center of an internal room, such as the engine room, or a hold for best results. The distribution hoses need to be spread out evenly to cover all the sensitive parts of the vessel without using lengthy hoses.

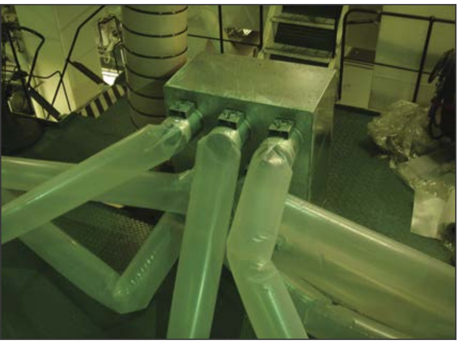

Fig. 8: Closed loop dehumidification system with even distribution set up

Navigation and Radio Room Accommodations

The navigation and radio rooms are usually above deck, where they are directly exposed to the elements. The exposure environment creates varying temperatures and relative humidity levels throughout the day. Since these locations all contain electronic equipment, woodwork, and textiles, it is important to control the humidity by placing humidistats where they can accurately read the relative humidity levels. Using humidistats, the dehumidification can be turned on when humidity rises above 50% and can be turned off once a safe humidity level is achieved. Controlling the humidity will protect woodwork and textiles from cracking and splitting. These locations are normally linked by the air conditioning system, which, when turned off and properly sealed, can be used to distribute dehumidified air throughout the accommodation, navigation, and radio rooms.

Closed System Dehumidification for Engine Room Spaces

Emphasis is placed at the lowest section of the engine room where moisture may gather; the heated dry air will dry the low area and then rise to other parts of the engine room.

Humidistats are placed in the dehumidified space to keep the relative humidity levels from exceeding the set value. Reactivation air is obtained from the air vent leading to the outside of the ship, and the wet air is vented out through a similar vent.

Case Study

A 3500 TEU (twenty-foot equivalent units) container ship was laid-up in the sea of Batam because of decreased demand for her services. The owner made the decision to complete a cold lay-up application for an unspecified period. (Due to privacy policies, the name of the vessel cannot be disclosed.)

Fig. 9: Part of system for cold lay-up of ship in Sea of Batam

Fig. 10: Part of solution was the shaft for air to enter

Challenges

The key challenge for the completion of the project included power supply for the units and the distribution of the air into the affected areas. The power was to be supplied by an onboard generator; however, there was concern that there would not be enough capacity to power the dehumidifiers and the necessary equipment to maintain the lay-up. The solution included a dehumidifier that provided an energy-efficient design to reduce the overall capacity needed. The equipment provided a 30% decrease in overall use, helping to reduce the overall power required and the long-term fuel costs for the generator. The logistics problem was solved by creating a unique labyrinth of ducting, manifolds, and plenums to effectively distribute the air in all the protected areas (Figs. 9 and 10).

Solution

The solution involved entry of the dry air system into two specific areas:

A) One desiccant dehumidifier that provided 2500 cfm (4000 m^3h) of dehumidified air and had a gas burner reactivator, making it less energy intensive, was dedicated to the engine room and accommodations deck

- Unit was placed on deck next to power generator.
- Dry air was channeled to the engine room and accommodation decks via flexible tubing connected to a butterfly joint with air damper.
- Flexible tubing was connected to an air-distribution manifold which distributes the air to various parts of the engine room via lay-flat temporary ducting.
- Air was channeled to various parts of the accommodation deck utilizing the air conditioning vents.
- Doors to rooms were sealed to prevent any air leakages.

B) One desiccant dehumidifier that provided 600 cfm (1000 m^3h) of air and also had a gas burner reactivator was dedicated to the forward mechanical room

- Dehumidifier was placed in the forward bow thruster room.
- 20 m of flexible ducting was used to channel air into the bow thruster area via air vent.

Costs for System

- Installation, shipping, and fabrication: $8,300K (US)
- Monthly rental rate (DH equipment only): $6,900K
- Estimated fuel for generators (per month): $3,400K

Conclusions

The shipping industry is laying up more ships then ever because the worldwide economic recession has reduced the overall demand for shipping goods and services. Ship owners are finding that laying up ships is a viable and profitable option for protecting their ships when not in use. Cold lay-up applications can create costly re-commissioning issues due to corrosion and mold created by excess moisture on board the vessel. The use of psychrometrics is the only true way to ensure that you are controlling the corrosion cell by eliminating moisture during a cold lay-up. The use of temporary dehumidification systems can effectively control moisture onboard, thus reducing these costly problems even for the longest lay-ups. Energy efficient units and engineered distribution systems provide an economical alternative to other lay-up alternatives. Desiccant dehumidifiers are the most effective and efficient equipment for controlling moisture in large areas such as container ships.

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About the Author

Russ Brown is currently the Global Business Development Manager for Munters Moisture Control Services and is based out of Indianapolis, Indiana. Brown has worked in the paint and coatings industry for the past 25 years in several capacities and for the Munters Corporation for the past 13 years. Within his current position, he has been active in the expansion of the core products and services for Munters Moisture Control Services on a global basis. Brown has a BS in Liberal Arts and Sciences from the University of Illinois. He is currently serving as President Elect on the Board of Governors of SSPC: The Society for Protective Coatings (SSPC) and is also active in the Construction Specification Institute (CSI), American Water Works Association (AWWA), and the American Institute of Architects (AIA).

JPCL

Controlling the Environment Inside Containment in Cold Weather

Editor's Note: This article appeared in JPCL *in January 2001*.

How do you decide what combination of heating, ventilating, and dehumidifying equipment you need to control the environment inside containment during winter?

Kenneth A. Jacobi
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The first step when developing a system for environmental control and heating is to determine the ventilation requirements. Where dehumidification, heating, and/or dust collection will be used, ventilation is the basic component of total air treatment.

The primary purposes of ventilation during blasting and painting operations in enclosed/contained areas are to protect the health of operators and assure adequate visibility for performing the work. In addition, proper ventilation is required to reduce contamination of freshly blasted surfaces by airborne particles and to reduce and remove solvent vapors during coating operations. The main factor in determining ventilation requirements during blasting is the size of the tank or containment structure. Other factors to consider are

- the number of blast nozzles operating at one time,
- the amount and type of coating being removed,
- the amount of lead or other heavy metals in the coating being removed,
- the amount of rust and rust scale on the surfaces being cleaned, and
- the breakdown and dusting characteristics of the abrasive and coating debris.

Ventilation is measured in terms of the volume of air movement over time, expressed as cubic feet per minute (cfm) or cubic meters per minute (cmm). A general guideline is to provide one complete air change every three minutes during blasting. The balance between incoming and outgoing air is very important. If too much incoming clean air is used while not extracting enough dirty air, excessive turbulence will result. This will place the inside of the containment under positive pressure. Subsequently, dirty air will escape and blow through any crack or opening in the containment or structure. Conversely, if too much air is extracted relative to incoming air, improper dehumidification and heating can occur. Air circulation balance is achieved only when the total amount of incoming air (heated or dehumidified) or untreated air (from blast nozzles or gaps in the containment) equals the total air removed.

For ventilation during painting, both the lower explosive limit (LEL) of the solvent vapor and threshold limit value (TLV) of the airborne toxic material must be considered. According to SSPC's *Protective Coatings Glossary,* the LEL is the concentration of an airborne compound (at ambient temperatures) below which an explosion will not occur if the mixture is ignited. The TLV represents the maximum level of airborne contaminants that will cause no adverse effect to workers who are exposed for eight hours.

U.S. regulatory requirements specify that ventilation volumes be sufficient to dilute solvent vapor to less than 25% of the LEL in non-confined spaces and less than 10% of the LEL in confined spaces (29 CFR 1910.146). Calculations of the LEL can be done using tables containing properties of solvents and knowledge of the percent volume of solvent in the particular coating to be applied. Doing these calculations for many different coatings has shown that the 10% LEL can be achieved in most cases by ventilating at the same rate that is used for blasting, at approximately one air change every three minutes. The air must be sampled with calibrated monitors to assure compliance.

Maintaining the paint vapor concentration below the TLV requires much larger volumes of fresh air compared to the volume required for LEL maintenance or for blasting operations. Due to space limitations and the cost of air handling equipment (and, if needed, dehumidifiers and heaters), supplementary methods of protecting workers' health are required. For that reason, respiratory protection equipment is commonly used along with the air handling equipment in accordance with industry standards as an alternative to needing very large volumes of air.

Air change is easier when the total volume of air inside the containment is reduced by localized containment (smaller spaces to ventilate). In addition, baffles are used to direct airflow along predetermined paths inside the containment. For larger containment volumes or cross-sectional areas of the containment structure, more airflow is needed.

Once the ventilation requirements are determined, the type of dehumidification unit (DH) and air heaters must be chosen. For cold weather work, dry desiccant dehumidifiers have advantages over refrigeration DH. Refrigerant units do remove moisture at all temperatures, but at air temperatures approaching 45 F (7 C) or lower, moisture from the air may freeze on the even cooler coils of the units, causing them to work less efficiently. With the dry desiccant units, moisture is removed at all temperatures without freezing. Moreover, these units produce dry air that is warmer than the ambient air.

One factor in determining the DH requirements is the type of coatings that will be used. Moisture-cured polyurethanes, ethyl silicate inorganic zincs, and some epoxies will require moisture to cure. This requirement must be taken into consideration when sizing the DH unit for a particular job.

Two other factors in determining DH requirements are 1) the difference necessary between dew point and surface temperature, and 2) the humidity level needed for blasting and for applying the coating specified. Condensation occurs when the dew point temperature is at or above the surface temperature. The general rule is to maintain the dew point temperature at least 5 degrees F (3 degrees C) below the surface temperature. Maintaining this spread or maintaining relative humidity at 40% or less will extend the time allowable between blasting and coating application.

One last item to consider is the possible need for additional heat. In cold weather or when warm days are followed by cold nights, a reduction in the surface temperature may cause moisture to form unless the dew point is low. Additional heat can help overcome this problem. It will help maintain the surface temperature and dew point spread while decreasing the relative humidity.

Heat may also be needed to make sure a minimum temperature is maintained for proper cure of catalyzed coatings. Electric heaters and gas and propane direct-fired and indirect-fired heaters can provide heat. But caution is needed. For instance, carbon monoxide fumes/exhaust from direct-fired gas and propane heaters may interfere with proper curing of the coatings and introduce contaminants on the steel surfaces. The amount of heat required may be reduced if cold-cure coatings or metallizing systems are used. Worker comfort may then be the main criterion for additional heat requirements.

After all these factors are accounted for, equipment suppliers can recommend the most appropriate combinations of equipment for a particular project.

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To engineer ventilation and climate control for containment in cold weather, you need to consider specifics such as weather conditions, size and make-up of the containment, types and sizes of the equipment to be used, and the scope of work.

The size and configuration of the enclosure and the purpose of the dust collector (the primary means of achieving ventilation) might be the most important considerations when starting the design process. The size of the containment generally determines the size of the dust collector. The larger the containment is, the larger the dust collector needs to be. In addition, you must determine whether the dust collector is being used for removing hazardous paint debris, controlling the LEL of airborne substances (e.g., solvent vapors), adding fresh air, or maintaining visibility for workers. For abatement, you might have to increase the size of the unit to meet air movement parameters for worker protection. However, if visibility is the only consideration, a smaller unit may be enough to meet your objectives.

Winter projects provide a challenge when attempting to heat space as well as remove air from the enclosure. Dust collectors can introduce large volumes of air into the space. This air is usually cold. A heater may not be enough to keep the containment warm. If non-hazardous materials are being removed, you might consider recirculating air after it is filtered through your dust collector. This process allows the air that is already warm to be continually circulated through the space while the heater provides the make-up heated air.

Where recirculation is not an option, and negative pressure (air pressure inside a structure that is less than air pressure outside of it) is required, a method of blending heated air with the cold air is necessary. This option allows for the dust collector to take in the exact amount of air needed. Use the following calculation to determine outlet temperatures:

$$\text{final temperature of air supplied} = \frac{(\text{airflow x ambient air temp.}) + (\text{airflow x heated air temp.})}{\text{total airflow}}$$

This solution often requires coordinating the operation of the pieces of equipment at the site to maintain necessary conditions. If negative pressure is required, you may need a larger heater than in the recirculation setup because more heated air will be required to overcome the cold outside air that is being drawn into the containment.

Examining weather conditions such as ambient temperature, dew point, and relative humidity is also necessary. Moisture load (humidity) is significantly less in cold weather than in warm weather. This may be the most important consideration when deciding on the dehumidifier size needed. (You probably don't want to eliminate the dehumidifier altogether. Although humidity is lower in cold weather seasons, having a dehumidifier is often a good practice to protect workers and the work from unexpected and quick weather changes. In addition, some heaters provide a source of moisture that may need to be counteracted by a dehumidifier.) The dehumidifier does not need to be as large as it would in warm and wet seasons.

These simple considerations should put you on the right track when designing a ventilation system for cold weather work. If you are still not sure, consult a climate control representative for advice.

Philip Powell
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To properly understand the interaction of heating and dehumidification requires a good knowledge of thermodynamics, but to simply choose the best course of action for a painting project, the following guidelines might help.

This discussion is concerned only with changes in temperature and humidity. However, as a practical matter, the required levels of temperature and humidity would depend on the type of coating being used.

Normally, you would use a heater when temperatures are low and a dehumidifier when humidity is high. When temperatures are low and humidity is high at the same time, you would use both. In some cases, a desiccant dehumidifier that heats and dries the air is an alternative to a heater and a condensing-type dehumidifier.

Where climatic conditions are borderline and only minor downtime is being experienced, I prefer not to use heating or dehumidification but to ventilate the containment with external air during sunny periods. This air, usually cool and low in humidity, is not too prone to condensation. This ventilation can be achieved by using only the fan of the heater or dehumidifier.

Here are three different circumstances in which ventilation would be needed during blasting or painting work.

1. When blasting, extraction fans and filters may be used to catch the dust. A suitable size of extractor fan would be 120% of the size of the compressor used for blasting. This will maintain a slight negative pressure in the containment area and prevent the escape of dust. In addition, a dust collector is needed.
2. During brush application or while paint is curing, ventilation should maintain less than 100 ppm of xylene (or whatever the acceptable worker exposure level is for the main solvent being used). The solvent level can be easily monitored using an air quality sampling tube.
3. When applicators wearing air-fed masks are spray painting, then ventilation sufficient to maintain no more than about 400 ppm of xylene (or the acceptable level of the primary solvent being used) will still allow time for a safe emergency exit from the spray conditions, if necessary. Under no circumstance, however, must the level rise above the LEL, which for xylene is 8,000 ppm.

Following are some general guidelines for using heating or dehumidifying equipment. (I have assumed a limit of 85% humidity and 5 C (41 F), but these parameters can change depending on the type of coating used.)

- Heaters and dehumidifiers should be of the indirect type in which the process air does not come into direct contact with the heating medium. Otherwise, such as in the case of a heater powered by diesel fuel, diesel fumes may contaminate the painting area.
- For safety reasons, heaters and dehumidifiers should not recirculate air through the painting area.
- Heaters should be run continuously. If they are run intermittently, condensation is likely to form on the substrate. This is because heaters do not dry the air. They cause only a temporary reduction in relative humidity. As soon as they stop, the temperature falls and the relative humidity increases, possibly causing condensation. For this reason, they are frequently counterproductive if used alone in conditions of high humidity.
- Dehumidifiers used alone in cold conditions will be ineffective because they have only a limited ability to raise the temperature.

JPCL

By Willian Dixon,
Dixon Engineering Inc.

Painting Water Storage Tanks in Winter

Editor's Note: This article appeared in JPCL *in May 2003.*

In the past few years, materials and gear for containment of painting work have advanced significantly. This is especially true for cold weather painting of water tanks. Significantly, with containment and heating, painting projects on water storage tanks can now proceed later in the year than previously. This change is important because summer is generally the worst time to take water tanks out of service since demand is highest. This article summarizes the challenges of painting in cold weather, describes the importance of ambient temperature and the role of containment in maintaining that temperature, and gives tips for success.

Challenges of the Cold

In Michigan and in most northern states, the coating season has followed the pattern of a very busy spring, a slow summer, a very busy fall, and no work in winter. Unless they are blessed with multiple tanks, owners of towers cannot remove a tank from the system during the peak demands of summer.

Cold weather painting requires modifying coatings to allow for application. However, when a coating is modified to improve one property, a different property is often sacrificed. In the past, every cold weather project required an analysis of whether the benefits of winter painting outweighed the disadvantage of a shorter-lived system. Many cold weather systems could be applied at 35 F (2 C) and could be recoated the next day, but they still required 28 days of cure before immersion. This extensive cure time, even during a period of low water consumption, is too long if the water system does not have multiple tanks. The key still is to raise the temperature to speed the cure.

Importance of Ambient Temperatures

Painting can be successful only with the proper control of ambient conditions. In the winter, the ambient condition most in need of modifying is temperature: the temperature of the substrate, the temperature of the surrounding air, and the temperature of the painter. Regardless of advances in low-temperature cure coatings, a cold, unhappy painter will complete a less than optimal project. Moreover, the machinery does not work as well in cold weather. For example, diesel engines and all battery-started machines are harder to start; water gets into gas lines; and moisture in sand pots freezes the sand because the moisture separator is frozen at the exhaust and is then bypassed. The painter's time is split between coating application and equipment repairs.

The colder it is outside, the more heat is needed to warm an interior space. The difference in temperature between the inside air mass and the outside air mass is the thermal gradient. The larger the thermal gradient is at the tank's surface, the greater the heat loss will be as both air masses try to minimize the temperature difference. Considering that the mass of the heated air of the tank is extremely low in relation to the outside air mass, heat rapidly dissipates from the tank. Heat dissipation is assisted by wind that blows away the heat lost to the outside. This phenomenon immediately intensifies the gradient between interior and exterior air, allowing more heat to escape.

A good reference for understanding winter conditions is chapter 10 of the American Water Works Association (AWWA) Manual 42, *Steel Storage Tank—Cold Weather Operations*. A heat loss chart in Chapter 10, M-42 (originally from the National Bureau of Fire Underwriters), shows that with an interior temperature of 42 F (6 C) and an outside temperature of 0 F (-18 C), a 250,000-gallon (950,000-liter) tank will lose 779,000 BTU in a 12 mph wind. (This relatively mild wind is measured at the steel interface, which is over 100 ft [33 m] in the air.)

Preventing Heat Loss

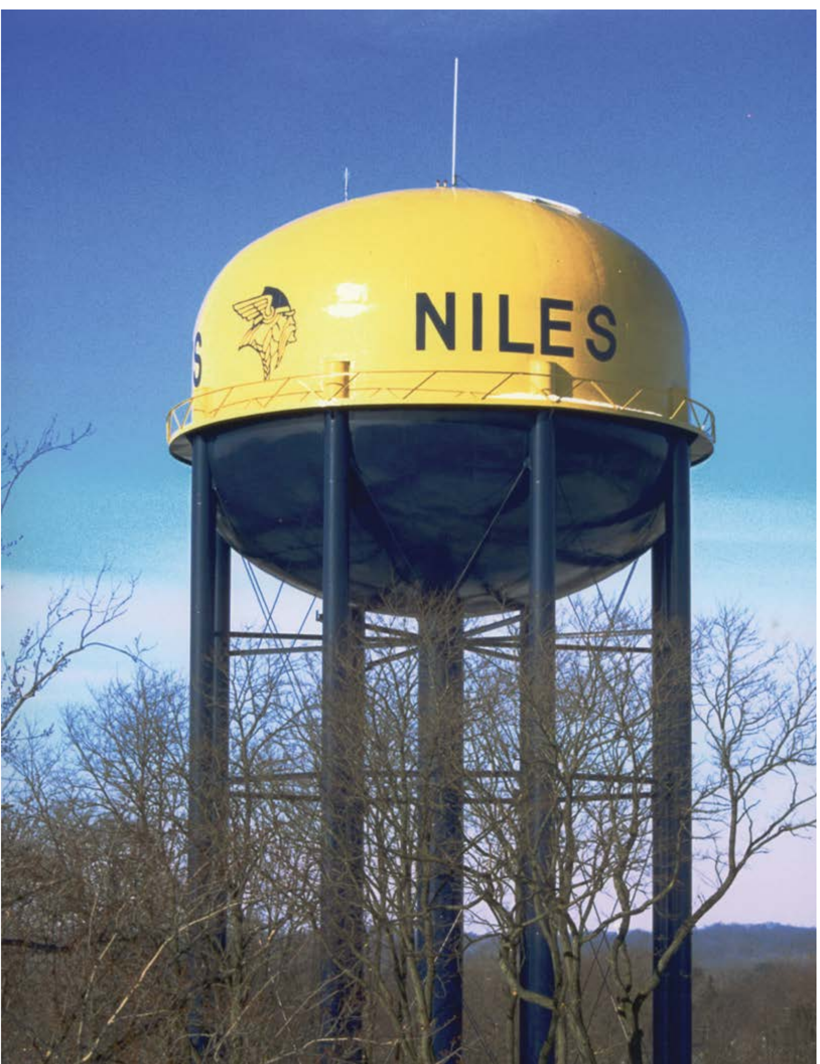
The only thing to prevent heat loss is the barrier between the confined air and the outside air. A steel barrier (i.e., the tank wall) is a good conductor of heat and a poor insulator. A concrete tank will at least offer some insulating value. If work is being completed on the inside of the tank, then thermal blankets or even a temporary insulated composite roof should be considered. If the project scope includes the exterior, then a SSPC Guide 6 (Guide for Containing Debris During Paint Removal Operations), Class 1A or 2A rigid containment or even a flexible containment system offers a small insulating value.

But the real insulating benefit of containment is the buffer zone added. It reduces the thermal gradient between the inside air mass and the outside air mass. The wind effect is now moved to the outside of the containment and is not as severe because the difference in temperature and extent of heat loss are not as great. Heat can be added to the containment area to reduce the amount of heat needed inside the tank. (However, all exhausts must be vented outside.)

Remember, proper ambient conditions for painting and, most importantly, the actual steel temperature are critical. It is possible to heat a tank and not achieve the necessary steel temperature if the outside temperature is low enough. This condition is more common on the lower shell sections because the heat tends to rise. (Even if an insulating blanket is used on the roof, where heat loss is greatest, the sidewalls will still rapidly transfer heat.)

Sample Project

One project in Michigan in the extreme northwest Upper Peninsula, completed in December and January, involved the construction of a new tank. Because of the nature of the facility, the tank had to be in service as soon as possible—winter delay was impossible. The contractor had to paint the wet interior (the portion of the tank in direct contact with water) before the tank was placed in service. The exterior and dry interior could be painted during the summer. The basebell and stem were constructed in the air, but the sphere portion was built on the ground. The paint subcontractor then built a rigid containment system using scaffolding and provided indirect heat during painting.



Painting in cold weather is now feasible, given the proper gear, materials, and conditions. Courtesy of Niles, Michigan

Because of the cost of fuel, the contractor tended not to fill the heaters at night and wanted to remove the heaters as soon as the last drop of paint was applied. He was required to maintain the heaters day and night until the coating cured (10 days). He also lost workdays when the heaters went off at night. Following the coating operation, the erection contractor lifted the sphere and welded it in place. In the late spring, when the outside was painted, the interior was checked and found to be in excellent condition. Turning off the heaters at night (until corrected) delayed the cure, but since the coating was a low-temperature curing material and the weather was mild, the coating was not damaged. If the weather had been as cold as normal, this could have led to failure. This project was successful because the heat was maintained in a containment area. It was too cold to have worked without the air buffer provided by the containment.

Tips for Specifiers and Contractors

Winter projects require specifications that are very thorough and that step a little over the line from performance specifications to prescriptive specifications. Performance specifications give the most flexibility to the contractor while prescriptive specifications give the bidders a more level playing field and more guidance. For example, we like to add equipment to our performance specifications. We specify the type of dehumidifier and the minimum size, but of course, based on the contractor's work layout (pipe runs [size and distance], point-of-entry into tank), the dehumidifier size may need to be changed.

Specifications must be governed by ambient requirements, and the contractor must thoroughly investigate the site. (All this equipment must fit somewhere.) He must consider design of his ventilation, dehumidification, and heating systems as well as fuel and manpower needs. If he has to heat for 24 hours, he might as well work for 24 hours.

The engineer is not done once the specification is written. He must review the bids but not on a low bid basis. Heating, ventilation, and containment plans should be submitted with the bid, and the award should be made to the most "responsible and responsive" bidder. Award of the contract must consider not only cost but also how the contractor intends to meet all ambient requirements.

The specification should allow for weather disruptions, define a weather day, and specify how many weather days are built into the project. Large snowfalls are better forecast now. Just as in the summer with severe weather, there will be some days when work should not attempted.

The contractor should minimize the potential for lost work through careful scheduling—for example, by planning for temporary interruptions. And the contractor should partition large tanks internally to reduce the chance of lost work as well as the heat and dehumidification requirements.

Finally, winters are usually windier than other seasons, so repair material for the containment should be available. Fabric for covering the roof should be able to hold two or three inches of snow and should be sloped to drain. **JPCL**

By Russ Brown
Munters Moisture Control Services

Considerations for Heating Liquid Storage Tanks during Cold Weather Coating Work

Editor's note: This article appeared in JPCL *in May 2003.*

Throughout the years, the coatings industry has gone through many changes. High-performance coatings have advanced to a point where they can be applied in almost any condition under nearly any circumstance to protect and increase the life expectancy of a steel structure. Today, coatings are becoming designer products that solve a number of problems common to coatings applications on tanks or other steel structures. For example, products today are being sensitized against moisture, corrosion, poorly cleaned substrates, and even mold or algae growth.

One area that has consistently lagged behind has been the coating of steel structures during cold weather. This does not mean that the technology has not been developed to address cold weather applications. In fact, a number of coatings manufacturers have developed high-performance coatings that can cure in temperatures well below freezing. Economics still plays a large part in the contractor's decision to use these coatings rather than providing the necessary auxiliary heat to meet the requirements for coating application (by raising the substrate temperature to 5 degrees F [3 degrees C] above the dewpoint and raising the air temperature for worker comfort). Often, however, low-temperature-cure coatings and artificial heating are used together to provide a sensible approach to cold weather application.

Photos courtesy of Munters

This article will begin with an overview of impediments to using heaters on painting projects and a comparison of low-temperature-cure coatings and heaters. It then details the types of heaters available and the principles of heat capacity measurement. The article concludes with a brief discussion of job site logistics when using heaters and safety with heaters.

Impediments to Heating Tanks

Heating steel storage tanks and vessels to meet the coating manufacturer's recommended substrate temperature requirements has always been a challenge. This challenge has revolved around the costs of providing such a service and, often, the difficulty of being able to meet the heat objectives. The ability to raise the surface temperature of a tank wall can require more heat and airflow than can be reasonably tolerated by the contractor or allowed by the relevant safety agencies. Imagine designing a temporary heat system that will require an internal temperature of 150 F (66 C) to achieve a surface temperature of only 50 F (10 C). The heat required to reach these temperatures would well exceed the comfort level that one could work in and could present serious safety issues. An additional consideration is the cost of the equipment needed to meet those parameters. Finally, one must always be aware of the amount of airflow that is being introduced into a confined space. Too much air introduced into the space without proper ventilation might cause serious structural problems because of the additional amounts of pressure being applied to the internal structure of the vessel. These issues often create dilemmas that all interested parties must consider before deciding if they want to move forward on the project now or wait for more temperate conditions to prevail.

Low-Temperature-Cure Coatings vs. Tank Heating

Low-temperature-cure coatings have significantly reduced the problems involved with applying coatings in cold weather. Often, the coatings contractor will provide low-temperature-cure products that only require a heater capable of generating enough heat to raise the temperature inside the tank to a comfortable level for working. With some low-temperature-cure coatings, it may not even be necessary to raise the temperature of the steel surface. The reduction in the heat required to meet the temperature specified would eliminate many concerns of the interested parties, including the owner, contractor, and perhaps inspectors from the Occupational Safety and Health Administration (OSHA). These low-temperature-cure coatings, however, can cost more than the epoxy tank linings commonly used in storage tanks. Often, the costs to upgrade to a low-temperature-cure coating do not make sense when compared to the costs of a traditional coating with the use of a temporary heat source. Therefore, it is often difficult to decide what avenue to follow when trying to complete a tank project in cold weather.

A major consideration for deciding on whether to use heaters for a project is the ancillary costs associated with them. The costs include shipping the heaters (which are often large), setting them up with the proper ductwork to carry heat into the tank, and budgeting for the fuel to operate them. Often, these are the necessary problems of providing a service that in the long run will establish the conditions to meet the most stringent specifications. In some instances, the need to complete tank work in a wintertime application is mandatory due to the principles of supply and demand.

Thus, the ancillary costs are often outweighed by the overall benefit of coating during off-peak times.

Fig. 1: All heaters discussed here are placed outside the tank because of size constraints, fuel fumes, and other safety issues.

Types of Heaters

The equipment supplied today for heat applications typically falls into three main categories: direct, indirect, and electric heaters. There are significant differences among the three types of heaters. The only similarity among them is that typically, the equipment will need to be placed outside the tank because of size constraints, fuel fumes, and other safety issues (Fig. 1). The direct-fired heater, often referred to as a tube heater, provides heat from a fan pulling outside (or internal) air through a flame, super heating the air, and delivering it to the intended space through ductwork. The heated air is not delivered with much velocity because of the low static pressure of the fan. This feature, however, does allow for the delivered air to become extremely warm.

The indirect-fired heater works much the way that a furnace heats a home. Outside air is delivered into a heat exchanger, is warmed, and then is pushed through a duct by a blower and into the intended space. Unlike the direct-fired heater, the air being warmed never comes into contact with an open flame. In fact, it is rare that a flame of any kind will be visible when operating an indirect-fired heater. Typically, a high static blower accompanies the indirect-fired heater and promotes its efficiency.

In most cases, direct-fired heaters are not acceptable for confined spaces like storage tanks. Although direct-fired heaters are extremely efficient (i.e., less energy is lost), they create carbon monoxide and carbon dioxide when the fuel is burnt during the heating process. These gases can be pushed into the work space, creating air unsuitable for breathing. Additionally, there may be the potential for an ignited particle to pass through to the work space and cause an explosion. Finally, direct-fired heaters create moisture during normal operation, which could cause condensation or flash rusting on freshly blasted steel.

In contrast, the indirect-fired heater has no direct contact with the flame, fuel, or burner assembly. The heated air that is delivered to the space is essentially as clean as it was before going through the heat exchanger. There is little chance for a burning particle to reach the confined space due to this design. Like the direct-fired heater, harmful gases are also produced during the combustion process of an indirect-fired heater. The difference, however, is that the indirect-fired heater vents the gases through a chimney to the outside. Also, the process of creating moisture as a product of combustion is eliminated. It should be noted that although the air is delivered at a high temperature (over 200 F [93 C]) with no new moisture added, one cannot substitute this type of heater (or any type of heater) for a dehumidifier while trying to protect a blasted surface.

A third type of heater, the electric heater, is commonly used for heating the interior of liquid storage tanks to meet extreme safety regimens. The electric heater works on an extremely simple principle. Ambient air is pushed over a coil (like those found in toasters) and heated. The heat delivered depends on the speed at which the air crosses the coils. There are no open or hidden flames, no fuel concerns, and no added moisture. Electric heaters are compact and affordable. They are often used when coating storage tanks in petroleum refining and marketing facilities because of their safer design. However, these heaters do have shortcomings. Electric heaters often do not provide the performance that can be expected from an indirect-fired heater. Although there are no fuel issues to contend with when dealing with electric heaters, they often require an enormous amount of electrical power, which many facilities cannot provide. The cost of heating for the project then rises because an auxiliary generator may be necessary to produce the electrical power to run the heater, and the generator takes fuel.

The temperature rise through a heater depends on the current ambient temperature, the safety limit switch, and the blower capacity. Any of these factors may reduce the overall heat produced by the heater and thus limit its effectiveness.

Understanding Heat Capacity Measurement

It would be unwise to leave the discussion of heater type without giving a basic explanation of the standard measuring unit for heat capacity: the British Thermal Unit (also known as a BTU). All the above heaters are designed to provide a specified number of BTUs for heating. The BTU capacity of a heater is a measure of the total energy consumed, not what is delivered to the tank surface. "One BTU is the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit at the temperature at which water has its greatest density (39 F [4 C])."[1] One cannot be certain that a specified temperature can be attained if one rents a 150-kW or 500,000-BTU heater (150 X 3,414= 500,000, where 3,414 BTU=1 kW). In fact, by slowing down the air speed of the heater or by supplying large amounts of additional air, one might affect the temperature delivered but not the total number of BTUs delivered. It should be stressed that the more efficient the heater is (the more BTUs delivered to the steel), the more effective the heating project will be.

Often, when a heater is used during warm weather (over 50 F [10 C], for example), the heater's limit switch will cycle the unit to avoid overheating the equipment. It is during these times that much of the BTU capacity is lost, and the heater is considered to be inefficient. One way to avoid short cycling a heater to gain maximum performance is to adjust the air flow. Other effective methods to reduce this short cycling are changing the nozzle size and restricting the gas flow to the burner. Obviously, knowing how to size a heater is extremely important, whether it is -50 F (-46 C) or 50 F (10 C). If the heater is short cycling, a smaller heater and a ventilation fan to achieve a specified airflow are most likely necessary. The understanding of the BTU is important so that one can adequately determine the right heater size to achieve the required surface temperature and maintain the specified temperatures during the project.

Benefits of Insulation

As stated previously, economics often plays a large role when deciding how to meet the temperature and dewpoint requirements for applying and curing coatings specified at a particular storage tank. We discussed earlier that the contractor will often apply low-temperature-cure coatings and use a minimal amount of heat to raise the air and substrate temperatures for worker comfort, coating adhesion, and coating cure. One other type of technology is quickly being added to many cold weather job sites. Insulation can reduce the overall costs of the heating project in winter applications and thus makes it a wise solution. As long as the steel substrate is warmer than the surrounding environment, it will lose heat (loss of BTUs per hour/sq ft) to that environment. Insulation comes in many forms, including heat blankets, aluminum foil-backed plastic bubble material, or mineral wool. In fact, any material that has an R-value might be considered adequate insulation. The R-value is a unit of measure for insulation that rates the effectiveness of the material to retain heat within the substrate. The higher the R-value is, the greater the insulating effectiveness and heat retention will be.

The use of a typical insulator like aluminum foil-backed plastic bubble will often reduce the overall costs of a heating project. The cost savings would equate to the use of significantly smaller equipment, a lower volume of fuel required, smaller unloading equipment, lowered electrical needs, and associated reductions in requirements. Consider the heat calculations provided here. Figure 2 shows that a typical 60-foot (18-meter) diameter by 40-foot (12-meter) tall, uninsulated ground storage tank would require a 3.5 million-BTU heater with a heat airflow of 17,000 cubic feet per minute (cfm). This calculation is based on an outside ambient temperature of 25 F (4 C) and a target substrate temperature of 50 F (10 C). For a variety of reasons, it is hard to fathom how one would be able to complete this work safely using only a heater. Most notably, the required internal air temperature to heat the steel to 50 F (10 C) would be a constant 129 F (54 C). This alone would create safety concerns.

In contrast, if one were to use the aluminum foil-backed plastic bubble material on the same tank, a 240,000-BTU heater unit at 4,396 cfm would be all that was necessary to meet the temperature objectives (Figs. 3 and 4). Additionally, a much more manageable internal ambient temperature would be achieved. Note the rough cost comparisons in Table 1 between the two situations. The table shows that even with the additional costs of insulation and installation of the material, the overall costs are significantly reduced. This reduction is primarily due to the fewer gallons of fuel required for the smaller BTU heater. Finally, it should be noted that if the insulation is not mistreated, the materials can be used on other projects, significantly reducing their costs.

Table 1: Cost Comparison between Insulated and Uninsulated Tanks under the Same Conditions*

	Insulated Tanks		Uninsulated Tanks	
Charges	**Amount**	**Cost**	**Amount**	**Cost**
Insulation	10,367 sq ft (933 sq m)	$4,146	—	—
Installation	10,367 sq ft (933 sq m)	$1,200	—	—
Heater/month	300,000 BTU	$2,805	3.5 million BTU	$7,160
Fuel/month	4,032 gal. (15,322 L)	$5,040	16,800 gal. (63,840 L)	$21,000
Shipping	Round trip	$1,200	Round trip	$4,500
Labor for set-up	N/A	$500	N/A	$800
Total		$14,891		$33,460

**All costs are estimated; data and costs are based on a heat calculator program. Sample screen prints of the program are shown on the next page (Figs. 2 and 3).*

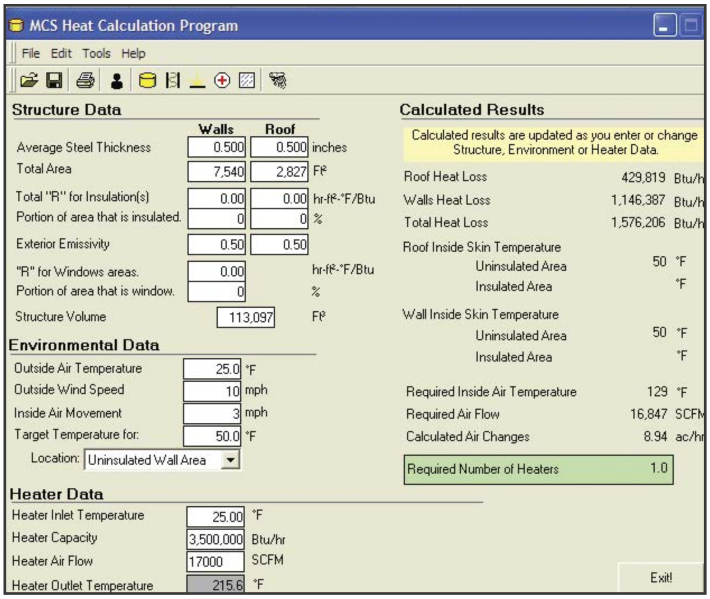


Fig. 2: Heat required to achieve 50 F (10 C) inside an uninsulated tank at an outside temperature of 25 F (-4 C)

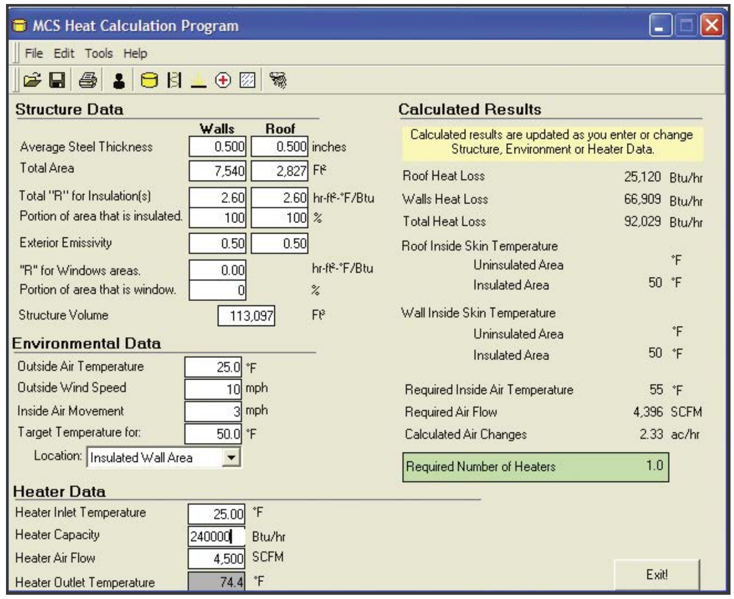


Fig. 3: Heat required to achieve 50 F (10 C) inside an insulated tank when outside temperature is 25 F (-4 C)

Job Site Logistics

Merely selecting the appropriate heater for the project does not mean that the specification will be met and the desired temperature will be maintained over the entire job. Often, the job site logistics are the key to ensuring the success of the project. Since many heaters are extremely large and heavy, it is important to know the space available on the site and the access it affords for unloading equipment. Placing the heater as close to the tank as possible will help eliminate pressure drop and overheating problems. Also, the shorter the duct is from the heater to the tank, the lower the heat loss will be through the flex duct walls. (Sometimes insulating this duct for longer runs helps.) If the heater is not self-contained (has its own power on board), be sure to have the power source close to the unit. If additional fuel tanks are required, be sure that they are close to the heater unit to avoid starving the burner while making sure that they are positioned to meet local and federal codes. It is important that job site personnel get adequate training on the heaters at the site, including basic functions (on and off), scheduled maintenance procedures, and safety requirements. An external monitoring device might be beneficial to provide hour-by-hour details on the conditions in the tank to ensure a successful project.

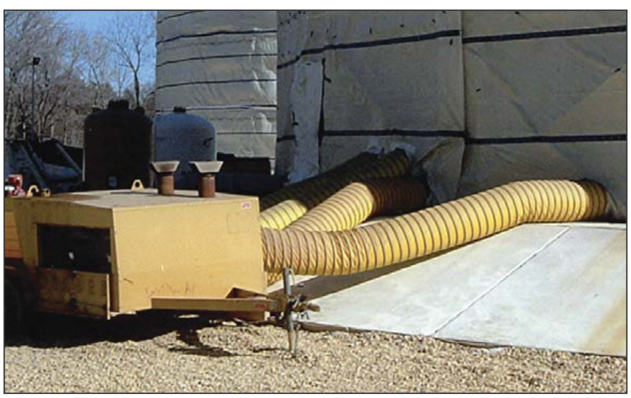


Fig. 4: Amount of heat required is significantly reduced when using 0.25 inches of insulation on the tank.

Safety

Finally, it is important to add a few words about safety, which is always a prime concern on any job site. Because they are less dangerous than direct-fired heaters, only indirect-fired or electric heaters should be used to warm air and steel for confined space. When using any type of heater at a tank site, it is important to incorporate its safe use into the job site safety program. This program will ensure that all personnel who come into contact with the heaters and the site are protected. This program relies heavily on communication among the heater manufacturer, owner, and contractor. It is important to have an open dialogue about heater operation, control, and safety concerns on site. Training on the equipment at the site is a must. Insist that the heater supplier include this in the initial proposal.

Summary

Today, the challenge of heating tanks to meet the ambient and substrate temperature conditions required for applying and curing high-performance coatings is greater then ever. For cold weather painting, selecting the appropriate technology—generally some combination of low-temperature-cure coatings, heaters, and insulation—is critical to project success. Additionally, all involved parties should discuss and manage job site constraints. Finally and most importantly, contractors should create a safety program on the job to reduce the potential for accidents at the site.

Reference

1. http://whatis.techtarget.com/definition/0,,sid9_gei213563,00html

JPCL

How To Set Up Ventilation in Confined Spaces

Editor's note: This article appeared in JPCL *in September 2009.*

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

Steve Wierzchowski is the technical director for Raven Lining Systems (RLS). RLS provides Raven and AquataPoxy epoxy coatings for the protection and renewal of water and wastewater infrastructure and also manages the nationwide network of Raven Certified Applicators.

Steve Wierzchowski, RLS Solutions Inc

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.

Ryan Webb, The Brock Group

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

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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. JPCL

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