Outgassing 101– Coating pinholing and prevention methods

How to navigate concrete outgassing induced pinholing with the Epoxytec CPP Series and other coating systems

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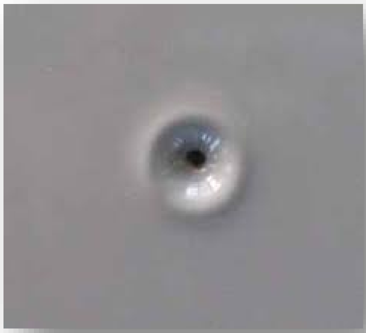
Whether dealing with seasonal temperature changes or ambient heat due to location, heat is a factor that wreaks havoc for contractors in the coating industry. When applying coatings on concrete, heat leads to outgassing which can lead to pinholing, an enemy of any coating applicator. To better circumvent outgassing woes, let's explore the phenomenon to better understand the solutions available.

The symptom

In the coating industry, when you inspect a cured resinous coating, you may occasionally see areas scattered with pinholes, cured bubbles, or lumps. This is only rarely found across the entire job. Typically, it's in isolated sections; for example, where the sun has been beating down on a section of a concrete slab.

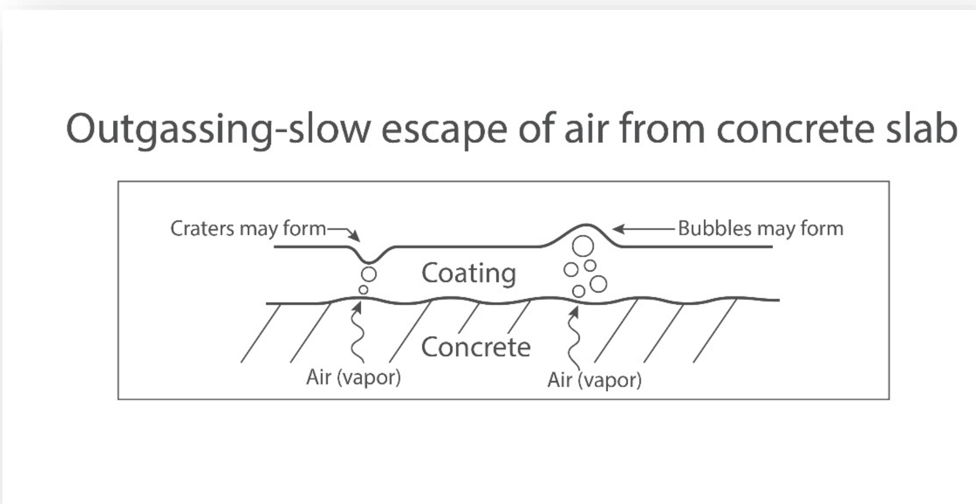
Sometimes these pinholes become more prevalent after aggressively prepping concrete, or with newer concrete. Maybe it's more noticeable when applying high solids or 100% solids coatings. Sometimes pinholes are few in number, and other times they seem to be scattered everywhere. So, what's going on here?



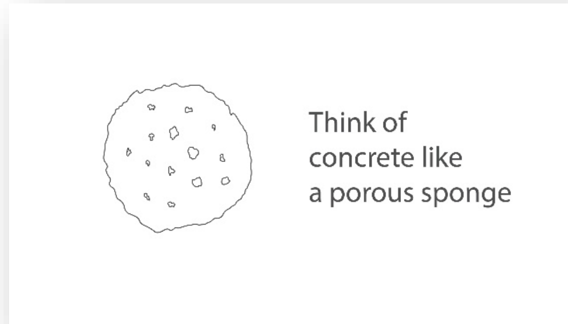
What is concrete outgassing?
How does it occur?
And why does it cause havoc with coatings?

While there are various reasons for pinholing to occur on coatings, in general, pinholes that resulted from material mixing, application method and handling are easier to understand and prevent. Examples include over-rolling while installing, mixing at too high a speed or mixing with an unsuitable mixing blade that brings in excess air before application even started. The way in which you mix and even apply product can introduce air into the final product and produce this effect as the air tries to escape. With thinner coatings, or water-based and solvent-based coatings, the air leaves more efficiently and oftentimes the film can resolve itself. With thicker systems however, especially 100% solids, pinholing can be more noticeable; air bubbles have a harder time passing through a film and often leave behind a pinhole right before the final cure. Nevertheless, these kinds of pinholes can be somewhat managed and controlled, or at least remedied in the future by prescribing the right tools and methods for mixing and applying. But what about pinholes created by outgassing?

The most common reason for pinholes on coatings is different than described above, and has nothing to do with the product, or its mixing or handling. Rather, it's an annoying natural culprit, frequently unpredictable and misunderstood. **The most common reason for pinholing when applying coatings direct-to-concrete (DTC) is known as "outgassing."** This is the slow escape of low-pressurized air (vapor) from a concrete slab while a coating, covering or overlayment is curing, resulting in pinholes on the finished film.



Concrete is very dynamic; it cracks, leaks, shrinks, grows, moves, breathes, absorbs water and air, and releases water and air vapor; and even undergoes chemical reactions. In addition, concrete is inherently porous and permeable.



It is somewhat like a sponge, with a network of voids, capillaries, microscopic air pockets, and stress cracks where air, moisture, and contaminants become trapped within its matrix due to its curing and hydration process, and simply because of its nature once cured.

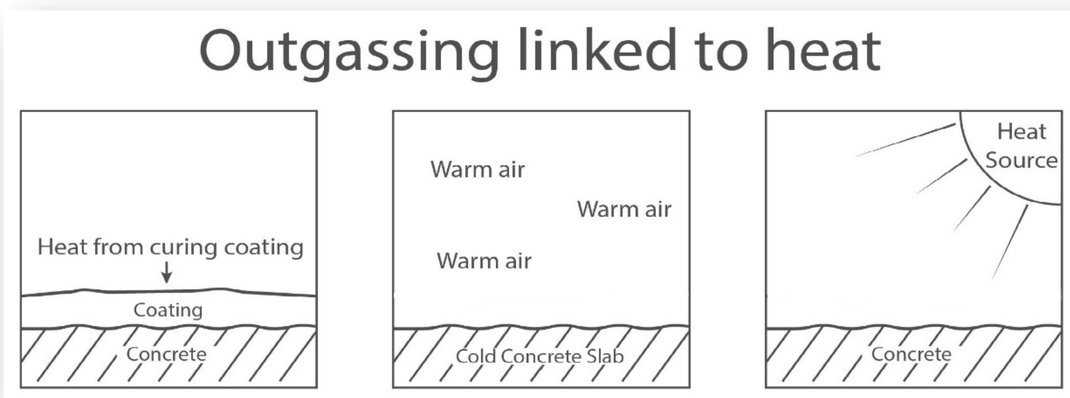
This open network interacts with naturally occurring conditions and physics, which results in moisture and air travelling in and out. Certain air voids are beneficial for concrete because they improve its durability, impact and freeze/thaw resistance. This entrained air allows room for expansion and contraction, preventing damage to the concrete. This is good for its overall resiliency, but can cause problems if barrier coatings are later applied to its surface.

Outgassing is a natural process that occurs in all concrete slabs. This process does not always cause problems for coating applications, but it sometimes can, especially around the summer months, when atmospheric pressure changes are frequent and the temperatures of substrates and air can rise and fall quite dramatically over the course of a day. However, all slabs are different. Some may produce a lot of outgassing while others produce very little. All concrete outgasses under the right conditions, but some less dense concretes do it more than others, while some older slabs do it less. Newer concrete poses more of a threat as it attempts to degas from its original pour and tries to eliminate that gas during its younger years, in addition to a cyclical outgassing tendency like all other concrete. But regardless, even aged concrete will outgas. Even well after a 28-day curing period (the industry standard) of concrete, for months and sometimes even for years, a newer concrete slab is still finding ways to expel deeply trapped gas which advances towards the surface to release.

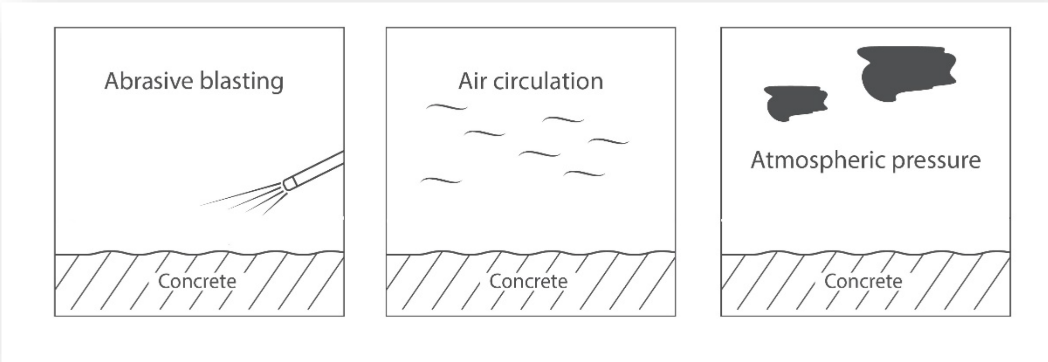
Temperature and environmental conditions are important factors contributing to outgassing. Vapor (air) moves in and out of concrete with changes in ambient air temperature and concrete temperature, as well as barometric (atmospheric) pressure, air flow, and humidity fluctuations. Like any element in nature, concrete attempts to seek equilibrium with its surroundings therefore releases air and water vapor that expanded when temperatures rise, and conversely, absorbs air and moisture when temperatures drop. The air expansion and release will typically occur as temperatures increase, and expanding air then travels through the concrete pores and capillaries often reaching the surface. The relief points of outgassing from pores can typically be covered easily with penetrating coatings, but outgassing under higher pressure may push and funnel through channels or capillaries and thus prove more difficult to manage at those points. Since concrete is like a sponge with residual moisture always within it, at times, the air migration to the surface will bring with it moisture vapor transmission (MVT), and sometimes other corrosives, chlorides, or contaminants. The direction of outgas travel is usually from the cooler side of a slab towards the hotter side, but not always. Air temperature directly over the slab plays a role, and if both sides of a slab are hot, it doesn't matter much. Gravity also plays a role, and the less dense heated air typically tends to travel upwards through pores, making its way to top sections of walls; or if on floors, usually on the surface where you are about to coat.

When barrier coatings are applied to a concrete surface that is outgassing, a blister or pinhole can form in the coating. This is because the pressure is trapped under a non-breathable coating or film, covering the relief areas like putting down a plastic sheet. Because the coating is fresh (liquid) and still curing, this will result in a defect or void in the coating during its vulnerable period of attempting to dry and cure. After a coating has finally cured, the defect will often appear as a small bubble on the surface or a crater-like impression (or sometimes a reverse crater with thicker systems such as the Epoxytec CPP Series, looking like a lump or bump).

Why does this entrained air want to escape? It is basic physics: air expands as it is heated or being drawn out as barometric pressure shifts. The more severe and common cases are from directly heated concrete or rising temperatures. The effect can be compounded by building more and more pressure, needing large relief channels or capillaries for vapor to escape. These usually form larger pinholes that are hard to plug up, even after layering coatings in multiple passes. Several factors are linked to heat: (1) the curing of most industrial thermosetting coatings is an exothermic reaction that generates heat (the thicker the coating, the more heat is generated); (2) if the slab is colder than the warmer air above it, then a temperature gradient exists causing air to flow from the colder slab to the warmer air; (3) super heating, such as direct sun, will create a rapid rise of vapor pressure from a sudden force of air expansion.



Other subtle factors at work would be air circulation over the slab that will also increase the tendency of air to want to escape the slab. In addition, outgassing can be aggravated when abrasive blasting, thereby opening more air pockets and bug holes. Outgassing (or off-gassing when chemically caused) may also result from degradation of concrete, where there is likely a pH imbalance, or a chemical interaction from a contaminant is reacting with the alkaline Portland cement. Acids, solvents, and other contaminants trapped within the concrete may create a very specific and noticeable area, where otherwise it may not be noticeable at all.



Here are various conditions that increase the likelihood of outgassing and pinholing:

- High air content, with less dense concrete. Air-entrained concrete substrates that has an excessive air volume ratio.
- 100% solids or high solids coatings. Thicker, higher viscosity coatings tend to penetrate less into the concrete's porosity, causing film floating and pinholing channels to form more noticeably, rather than penetrating and collapsing into the pores.
- New concrete. In addition to cyclical outgassing, younger concrete could still be attempting to expel original entrained air.
- Blasted concrete and surface preparation. Surface prep is necessary to optimize coating adhesion, but unfortunately opens pores to facilitate outgassing.
- Heated concrete (i.e., in direct sun). Hot concrete will cause expanded air vapor under pressure, creating relief channels through the porosity of concrete slabs, and especially through channels of micro-cracks and capillaries, at a more extreme rate and requires a longer time frame to resolve.
- Rising temperatures. A slow expansion of moisture and air will create vapor rinsing to the surface. In addition, if the slab is cooler than the air above it, this temperature differential can draw air out of the concrete.
- Barometric or atmospheric pressure changes. Fluctuating atmospheric pressure will force air and water vapor into concrete and draw air and water vapor out of concrete.
- Contaminants in concrete or pH differentials, degrading concrete. Acids and other contaminants trapped in concrete could cause chemical-induced off-gassing from decomposition or adverse pH interaction and reactions.
- Thicker layering of exothermic coatings. Most two-part, thermosetting industrial coatings cure via an exothermic reaction, creating their own heat from a reaction. This heat could create vapor, especially with a thicker mass or more aggressive curing agent (reaction). This is further exacerbated when heated material is applied (i.e., heated spray applications)
- Continual air flow. A continuous flow of air over a porous concrete slab could inconsequentially entice a molecular flow of air outward.

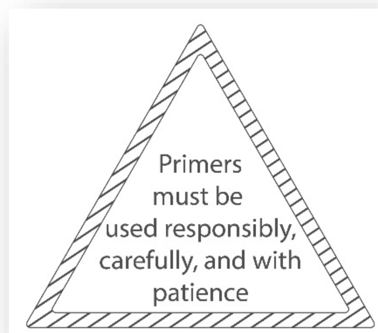
Prevention methods

So how is outgassing prevented? There are a few industry-proven methods and techniques. Some may offer a minor improvement while others can resolve issues quite dramatically. **A combination of many of these methods is always the best approach.**

Knowledge is key. Observing and learning the conditions that create outgassing is imperative when figuring out what to prescribe in order to reduce its occurrence. Therefore, understanding what creates a more dramatic effect versus a minor effect will enable you to decide if the best results will be achieved by, for example, waiting for more suitable ambient temperatures, or using a primer, maybe a resurfacer, or perhaps layering material in successive passes, or some combination of strategies. When in doubt, experiment on one section and observe. But when you know aggressive outgassing is inevitable, look to prescribe a combination of methods to maximize the likelihood of reducing or eliminating outgassing, and hence pinholes.

<u>Penetrating primers</u>

The most widely known preventative measure in the industry is to seal the concrete after surface preparation with a low-viscosity, deeply penetrating primer such as *Epoxytec SE Primecoat or SE-d Primecoat*. However, although this is a popular method in the grand arena of paints and coatings, primers may be insufficient to cope with severe outgassing under high vapor pressure from direct heat expansion, and this method may create other challenges to now manage or worry about.

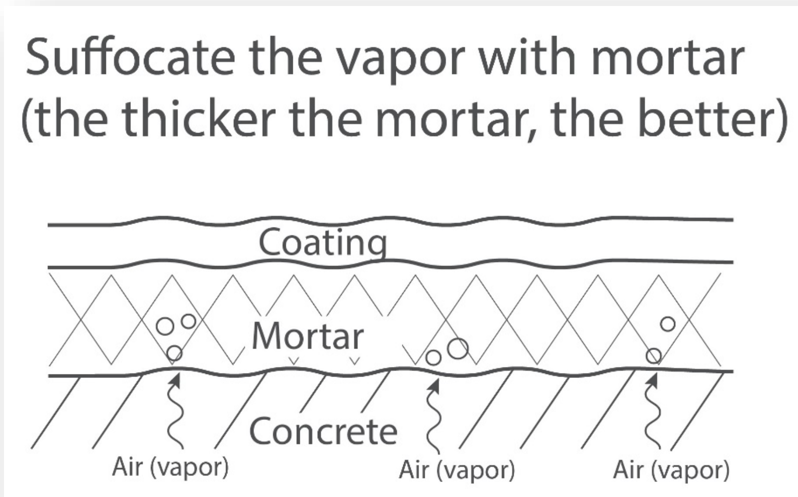


Low-viscosity primers may seal some low-pressure pores, but for higher-pressure channels or capillary vapor exit points undergoing a rapid increase of pressure from the direct heat of the sun, primers will be unable to collapse and plug those holes. In addition, many penetrating primers are either solvent-based or water-based, and that means sorting out and contending with the possible introduction of water (vapor), over-priming issues, recoat windows or solvent entrainment. Using a primer is a matter of weighing the pros and cons.

Usually, for an effective system using only priming as your first method to defend against outgassing, multiple coats would likely be needed or back-rolling often would assist in collapsing any pinholes in the primer itself. Circumstances in which they do help are where they are used responsibly and carefully and with patience, allowing them time to cure correctly, to seal the initial low-pressure or no-pressure pores that have not yet gained much vapor pressure.

<u>Breathable high-density mortars or polymer slurry coats</u>

If the situation allows it, the use of semi-breathable, high-density, early development resurfacing mortars such as *Epoxytec's Mortartec Series* is better than priming in most cases. Minimizing (or completely eliminating) outgassing by applying a semi-permeable, thick barrier material such as a mortar or semi-breathable polymer slurry topping systems allows the vapor from air and water expansion to release into the matrix (absorbing and capturing it), while thick enough to prevent it from surfacing through, or least minimize a large percentage from doing so. In short, suffocate the vapor with mortar. Drier mixes, such as lightweight or lower density mortars, don't work as well as polymer or resin-rich, high-density formulas such as *Mortartec Ceramico*. *Mortartec Ceramico* is a great choice as its epoxy-curing mechanism assists with thick gelling for a thinner mortar application requirement, but one that still makes it hard for outgassing to reach the surface. The thicker the better, of course, which is why *Mortartec Silicate* also works well in many instances.



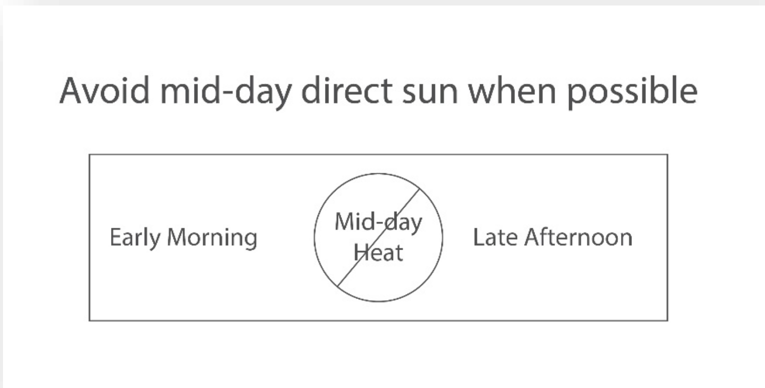
Temperature awareness

Excessive outgassing can be caused by a rise in temperature. When temperatures increase, air and moisture vapor in the concrete heat up and expand, thus increasing the vapor pressure and subsequently the outgassing. Even if the heat isn't seemingly hot enough to create air expansion, outgassing can still be triggered by the interaction of hotter air passing over the cooler concrete slab. An increasing surface temperature as ambient temperature rise, is a strong indication that outgassing will occur, especially after a slab has been sitting cool prior.

You can prevent outgassing by making sure the slab temperature is equal to or greater than the overhead air temperature, thereby reversing the air flow (shading the area or applying product in the late afternoon or better yet, into the evening when temperatures are decreasing). In this case, assuming the barometric pressure is also benign at that moment, you may actually observe product dimpling as it is "sucked" into the pores and capillaries. This makes for incredible bond strength to the substrate. This condition can be brought about naturally when cooler air travels over a warmer slab; also if logistics allow it, by pre-heating the slab by indirect heat or increasing the air temperature sufficiently to bring the slab temperature up to ambient conditions, then shutting off the heat and allowing cooler air to engulf the warmer slab. Measuring substrate temperature against the overhead air is usually the best and most proper method of reducing the occurrence of outgassing, especially if the preference is to use no other mitigating material or method.

Avoiding direct sun

No matter what time of day, it is best to avoid direct exposure to sunlight as much as possible. Direct sun or direct heat can supercharge the expansion of air and moisture, and therefore create the most aggressive occurrence of outgassing, which is typically a rapid buildup of higher-pressure channeling out towards release points.



This superheating effect can cause outgassing to last a while longer, even as cooler air may come in later in the day. Even as cooler air approaches towards the evening, direct heat all day may still have expanded air that craves a release of pressure even hours after the sun sets, and this pressure may be too high for other forces to play out. Once the expanding air pressure does finally achieve equilibrium, then the effect can dramatically reverse at a tilting point in the evening, assuming the slab is still slightly warmer and cooler air is passing over — and, of course, assuming other desirable environmental conditions are present. When this tilting point happens however can be somewhat unpredictable, but will be noticeable.

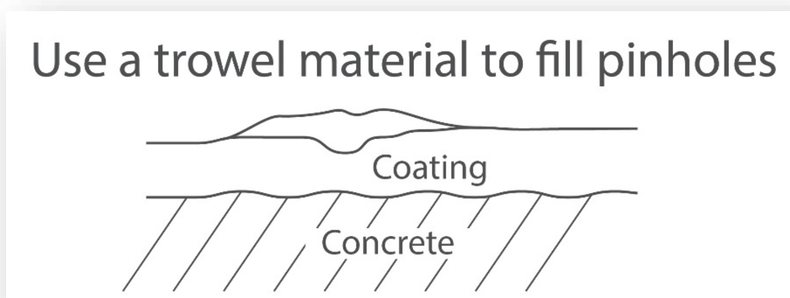
Atmospheric pressure and air flow

The unpredictability of outgassing can be annoying, especially when all else seems to have been attended to (shade, cooler air, etc). Yet there are pinholes, leaving you scratching your head. There could be a hidden culprit. Barometric pressure changes (low vs. high pressure) can actually push air into concrete and vacuum it out again, over and over. When barometric pressures change, outgassing could occur even when all other conditions are ideal. Summertime and seasonal weather cycles could leave you dazed and confused. When weather fronts are on the horizon, it's perhaps best to wait for some balance, if you are able to wait.

Layering

Layering is a popular method that Epoxytec recommends to assist with minimizing the pinholing from concrete outgassing, especially with the *Epoxytec CPP Series*. The Epoxytec CPP Series is intended to go on thick, and like other high-build epoxy coatings, it's thermosetting. The thicker it goes on, the more mass and generated heat. There is not usually enough heat to cause major concern, but cooking in direct sun or if sprayed "hot" would compound the problem of overheating. The trapped air, and vapor would begin to build and look for a way to escape. Starting with a thinner layer of material would keep the temperature lower, and actually create insulation (radically reducing the outgassing effect caused by the exothermic reaction of future buildup) for the subsequent build-up coats on top. The thinner the increment, the lower the exothermic effect.

However, this is not the primary reason to layer. The primary benefit is to create a "tack" coat. A tack coat is the first coat applied, intentionally thin, to allow for lower temperature exotherm and time to "wet" into the surface and "gel" up, creating a semi-solid tacky barrier coat which seizes lower pressure outgassing, and subsequently plugs up and collapses into most of the pores. The applicator will have to allow time for each increment, especially the first coat, to semi-cure (or gel) and gain some strength. After initially setting up, each layer will further reduce any outliers. Each layer will facilitate the plugging of stubborn pinholes still making their way through the previous coats. As pores get constrained, and pressure slows or seizes from that release point, the product can fill in with subsequent coats if it hasn't already collapsed into the pinhole. This is not guaranteed, as higher pressure vapor channels can push through even the thickest epoxy coatings (especially from aggressive direct sun heating), but it is certainly a technique that will blanket the surface and reduce a percentage of the pores and pinholes on each pass, if patience is afforded to allow each layer to tack up or gel.



This method takes time and does slow down progress. Close observation is required during the initial coating. Once it is gelling, the material will be semi-firm. With the *Epoxytec CPP Series*, this would even allow time to push material manually into stubborn, large pinholes. The thicker version *Epoxytec CPP* (in trowel-grade form) could also be used to chase larger, higher pressure pinholes in between coats, to hand-apply directly over a challenging outgassing pinhole. If all else fails, Epoxytec would even recommend an epoxy stick to plug these holes, such as *MCOR's InstaFIX Epoxy Stick.*

Combine prevention methods for a holistic approach – "The Best"

It is important to gain experience by learning about outgassing, to be aware of the conditions that cause it to occur (especially when it may occur aggressively), and to know about the various techniques and methods to reduce or prevent it. Paying close attention is critical during summer months or in hot environments. A combo approach will certainly provide better results than prescribing just one approach.

Being aware of the conditions that lead to outgassing is the first step in preventing it. Following the precautions mentioned here, and planning your installations to avoid the conditions that cause it, can greatly reduce the risk of outgassing. This will save you the expense and aggravation of rectifying pinholing problems after the fact.

The applicator should try to program coating application in layers if possible, to coincide with a cooling trend, usually late in the afternoon or (even better) into the evening, allowing time for any remaining air to have stopped expanding, thus having pressure and temperatures reaching equilibrium.

Before starting a job, surface temperatures should be monitored to determine the cooling and heating trends of the areas to be coated. If dramatic weather events are approaching or to be predicted, rescheduling the application would help eliminate outgassing induced by atmospheric pressure changes.

A combination of these methods is best. Of course, not all projects will permit these luxuries of time and logistics, but when possible, these methods will minimize or eliminate outgassing and pinholes. In the list below, start from the top and use as many methods as possible to increase your success rate in mitigating outgassing and pinholes:

1. Avoid harmful conditions.
    - Avoid barometric (atmospheric) pressure shifts, such as weather fronts.
    - Apply coatings in the late afternoon or evening, when the slab temperature is equal to or greater than the overhead air temperature. Using shade to keep the air and slab temperatures equal can also help, or use temperature control methods, if available.
    - Avoid superheated concrete or concrete exposed to direct sun; if unpreventable, allow the expanded air plenty of time to outgass and release.
2. Use a high-density resurfacer (such as the Epoxytec Mortartec Series) when allowed and budgeted — the thicker, the better.
3. Layering. If time is on your side, when possible, spray a thin tack coat and allow it to gel (“tack up”) before applying subsequent layers to your final DFT. Even better, do so in multiple passes, allowing each pass to gel.
4. Primers. If you can manage properly, being careful with required dry times and recoat windows, and if you know that outgassing will still have to be contended with, and if nothing else is available, use a primer as a last resort. Back-rolling is best.

NOTE: Epoxytec is sometimes asked about densifying the surface. While it is possible to “densify” a concrete surface, this technique is contradictive to most coating application needs. Coatings instead typically prefer the opposite approach, which is to optimize adhesion with mechanical anchoring and profiling, thus opening the pores more, to permit greater “wet in” or resin penetration. So, while high-pressure water jetting, blasting, or abrasive methods may trigger outgassing, it is a necessary tradeoff for better adhesion of mortar, primers, and DTC coating.