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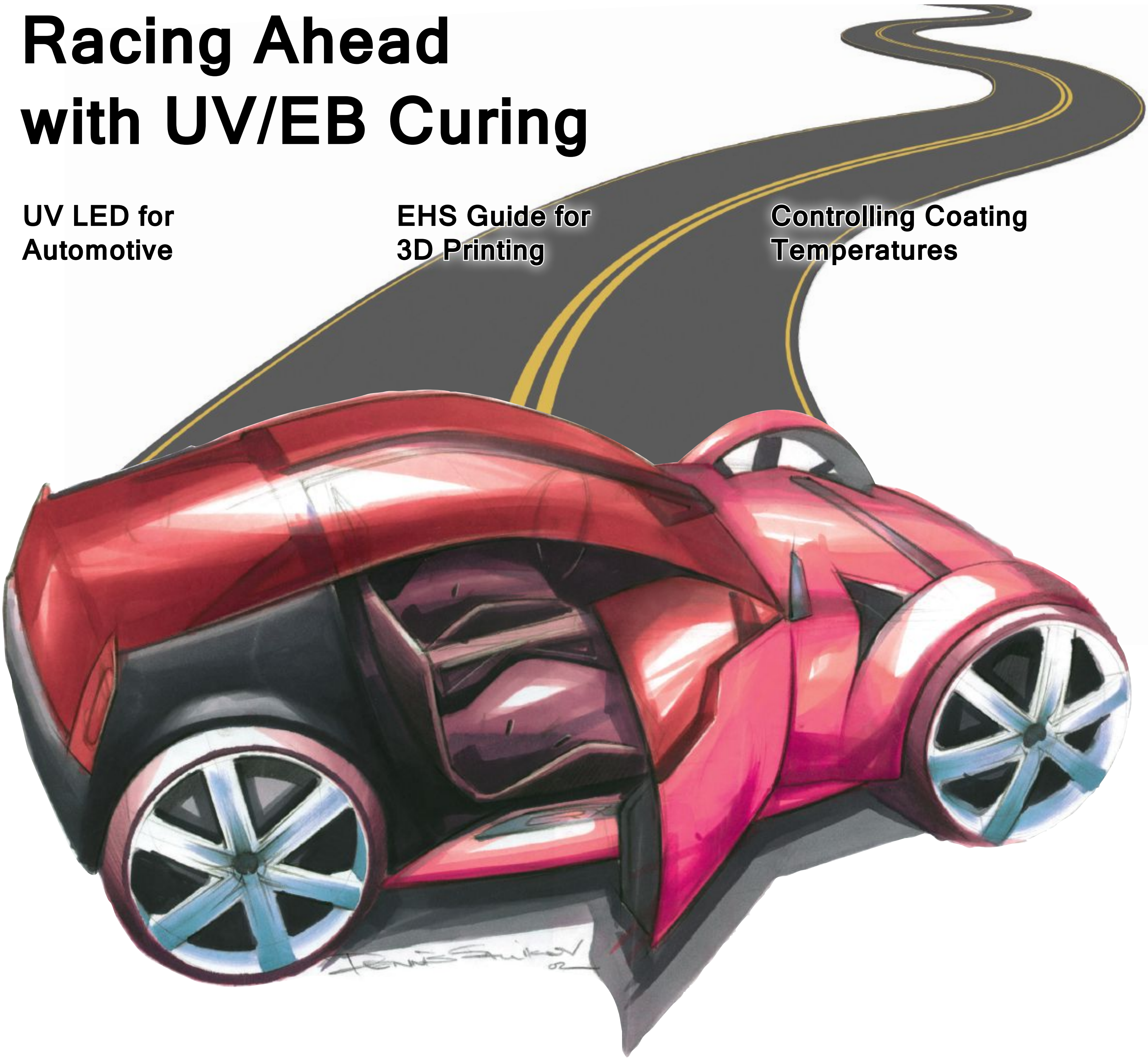
UV+EB TECHNOLOGY

Racing Ahead with UV/EB Curing

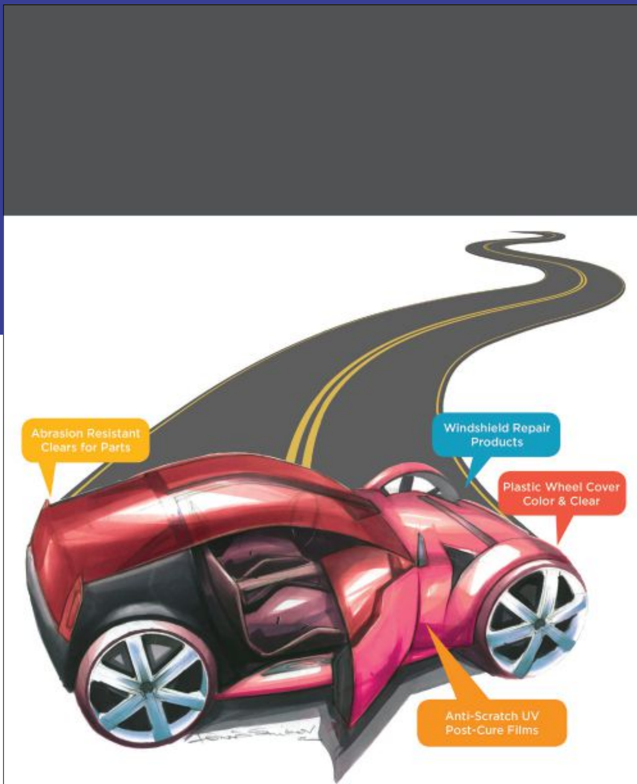


UV LED for Automotive

EHS Guide for 3D Printing

Controlling Coating Temperatures

RADTECH THE ASSOCIATION FOR UV&EB TECHNOLOGY Official Publication of RadTech International North America



Outlook for Automotive Coatings on page 30.

ON THE COVER

Cover photo: RadTech North America International reissued a brochure featuring uses of UV/EB curing technology in automotive applications. This issue's cover features an image from the brochure, courtesy of RadTech.

The cover was finished by Royle Printing Company, Sun Prairie, Wisconsin, using a multi-step UV-curing process called Rough Reticulated Strike-Through. First, the 4-color process was laid down and a UV varnish was applied as a spot application in the areas that did not receive the gloss UV treatment (photograph and copy). The UV varnish was cured with UV lights, and then an LED curing system was used to cure the 4-color process inks. A flood gloss UV was applied over the entire cover, which "reacted" to the UV varnish and created the matte varnish – staying glossy in the areas that were knocked out to receive the gloss UV. The final step was a pass under another UV curing system to cure the coating. This process was performed in one pass on press.

DEPARTMENTS

FEATURES

By **Michael R. Bonner,** vice president of Engineering and Technology, Saint Clair Systems, Inc.

The Importance of Controlling Coating Temperature in UV Applications

In modern coating operations, temperature-related variations can result in significant quality problems with film build, color match, surface finish, gloss, adhesion, etc. The first part of this series – shared in the January edition of UV+EB Technology ENews – examined the intractable relationship between temperature and viscosity in modern coatings and compared the behavior of 100 percent solids UV cure coatings with more conventional solvent-borne and waterborne systems.

This article examines the two most common application processes: spraying and rolling. It also explores how modern temperature control systems can be used to turn temperature into a tool that can be used to control the outcomes of these processes.

Spray Processes

With just a sampling shown in Figure 1, there are nearly as many different spray processes as there are engineers to design them. But, no matter the details, they all boil down to the basic design shown in Figure 2.

In addition to the basic system layout, Figure 2 shows calculated temperatures at various points throughout the system. Though the temperature may be important to maintain a consistent viscosity and to control pressure drop at various points throughout the fluid delivery path, only one temperature determines the quality of the finish: the temperature of the coating leaving the nozzle. This is the point-of-dispense.

Viscosity Impact on Atomization

One of the most significant factors in spray application is consistency of atomization. The orifice size and shape is fixed in any given applicator. The atomization produced by this orifice is a function of the flow, pressure and viscosity of the coating presented to it. For the purposes of this discussion, and in most practical applications, we will assume the pressure is being held constant by a regulator. Therefore, the only variable to be considered is viscosity.

FIGURE 1: *Various spray processes*

During atomization, the higher the viscosity, the larger and heavier the droplets become. This

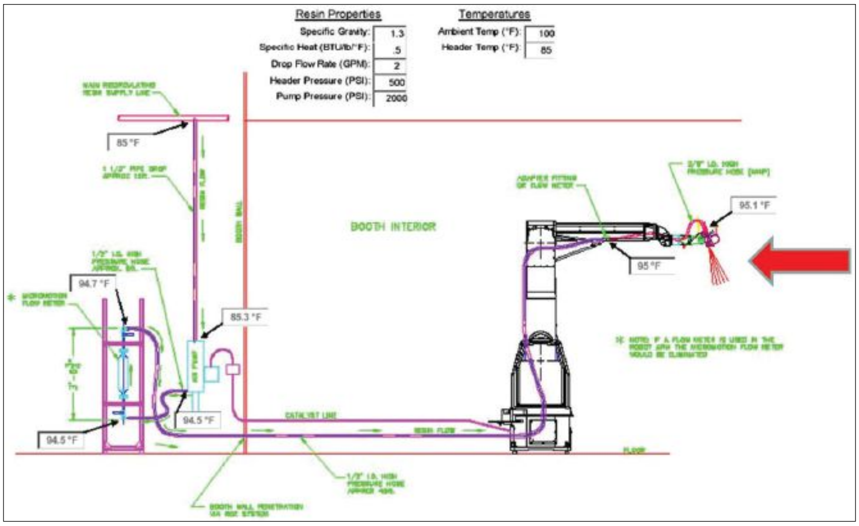


FIGURE 2: *Basic spray system design and thermal model*

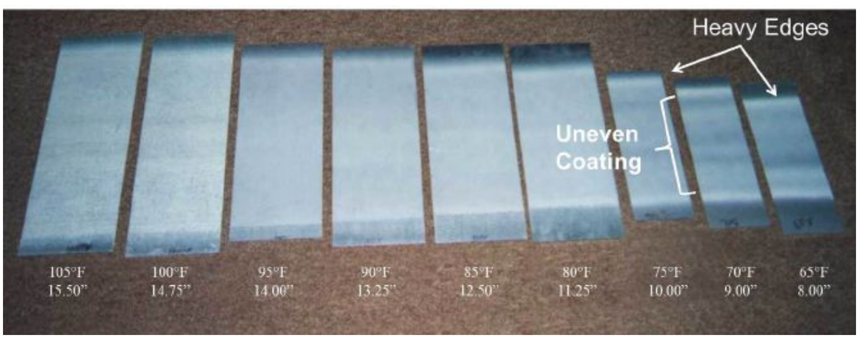


FIGURE 3: *Effect of temperature on spray pattern*

generally results in a heavier film build, which is the primary factor in color match. It also will impact flow-out and, therefore, surface finish qualities, such as gloss. Adequate film build is essential to good finish quality, but excessive film build can have a negative impact on the result. Too much coating on the surface increases usage rates and can result in runs and sags that require rework, both of which add to the cost of the end product. Often overlooked is the fact that this heavier film build can result in orange peel and reduced adhesion, as uncured material is trapped in the lower layers of the film during the curing process.

Conversely, the lower the viscosity, the smaller and lighter the droplets become. These lighter droplets are more susceptible to being caught in the booth draft and drawn away from the designated target. Even in electrostatic systems this can result in greater overspray and lower transfer efficiencies. This generally results in a lighter film build, which also can have a significant effect on color match. A more subtle effect is that these smaller droplets present more surface area in contact with the air. It is natural that a temperature change occurs through the contact between the ambient booth air and the droplet's surface. The rate of temperature change is determined by the size of the droplet and the surface area exposed to ambient air but results in a shift in viscosity as the droplets reach the target surface. This often is an increase in viscosity caused by a reduction in droplet temperature. If the increase in viscosity is too great to facilitate flow-out, then gloss, orange peel and other surface finish anomalies result.

In short, consistent atomization is essential to consistency of deposition rate, which is the key to transfer efficiency, color match, surface finish and adhesion. Atomization is directly affected by viscosity, which is directly related to temperature; therefore, consistent atomization requires consistent temperature.

Viscosity Impact on Spray Pattern

Atomization is not the only delivery factor affected by changes in viscosity. Spray pattern also is affected. When all other factors (orifice size, pressure, path, speed, distance, angle, etc.) are held constant and temperature is varied, the pattern dispensed changes dramatically.

To create the coupons shown in Figure 3, orifice, pressure, distance and angle to the surface were held constant with a robot while the coating was sprayed. Only temperature was varied. The coupons were sprayed and the spray patterns measured. The figure shows the effect on spray pattern across a 40°F (22°C) change in temperature. Here we can see the wide spray pattern and thin coverage from the high atomization rates at elevated temperature and how the pattern narrows as the droplets grow when the temperature is reduced. We can see the thin deposition due to the wide fan pattern above 95°F, the evenness of the pattern in the 90°F to 95°F range and the uneven distribution and heavy edges as the temperature falls below 85°F.

An operator must compensate for these changes by making adjustments to the pressure regulator or through eye-hand coordination, adjusting overlap and re-spraying thin areas. At lower temperatures, the overlap area can produce too heavy a film build, resulting in striping, run and sag, orange peel and other finish issues discussed previously. When robotics are employed, no eye-hand coordination is involved, and the problem can be repeated over and over again.

This change of viscosity can be gradual as the temperature climbs throughout the day (or falls throughout the night), or rapid (say, from a bay door opening near the process), as thermal losses create uneven temperatures throughout the dispensing system. This is especially true when elevated temperatures are employed.

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Figure 4 shows the thermal loss from a dispense valve to ambient, over time, on a robotic spray system. When the system is allowed to sit idle for more than few minutes (breaks, shift changes, part changes, downtime, etc.), the loss is significant.

Figure 5 shows the effect on the spray pattern when the valve is allowed to reach a 71°F ambient in a system set to run at 85°F. While the lower-temperature material in the valve is being sprayed, the pattern is narrower and the deposition is heavier. As the warmer material reaches the valve, the fan pattern widens and the film-build drops proportionately. The rate of thermal loss increases directly with the ΔT between the surface and ambient, making this situation even more difficult at elevated coating temperatures. This is just one of the reasons that heat-only systems often do not produce the expected control. This same scenario applies to the supply hose and spray gun in manual operations and is a short-term, unpredictable situation that is difficult to compensate for, even by an experienced operator. For this reason, many operators will spray the contents of their supply hose to waste after a period of not painting so this situation will not create a defect. A robot also can be programmed to do the same. While effective, this quality consideration comes at the cost of increased coating usage and waste disposal – both of which increase process cost.

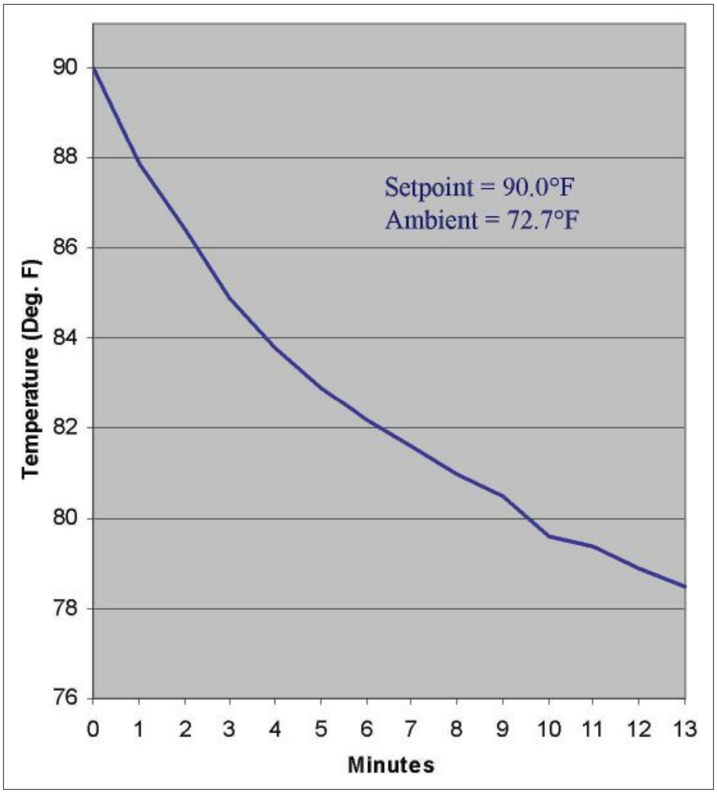

FIGURE 4: *Thermal loss to ambient*

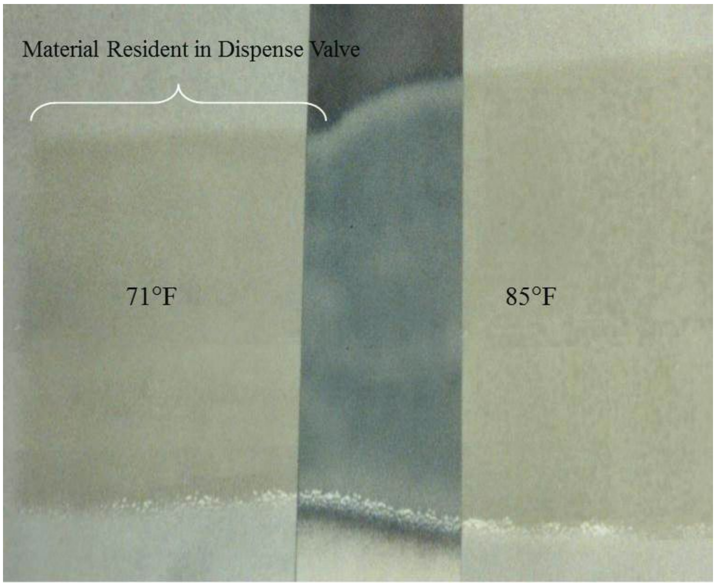

FIGURE 5: *The effect of thermal loss on spray pattern*

Roll Coating Processes

As shown in Figure 6, roll coating processes also come in all different shapes and sizes. One of the fundamental differences between spray application processes and roll coating processes is that, instead of being sprayed from a single-point orifice, the coating is applied all along the width of the face of the applicator roll. Any variation of viscosity (read: temperature) along this path will result in a variation in coating film build. In addition, friction between the rolls generates heat. Therefore, the mechanics of the coating system will endeavor to increase coating material temperature (and, thereby, reduce its viscosity) throughout the coating cycle. Analysis of such a system requires a different approach to measurement, as shown in Figure 7.

Figure 7 shows that probes placed in the coating at the nip sense the temperature variations across the width of the applicator roll. This is the last opportunity to measure the coating prior to application and, therefore, the best place to take such measurements. We refer to this as the "thermal profile."

FIGURE 6: *Various roll coating processes*

FIGURE 7: *Measuring temperatures in a roll coating system*

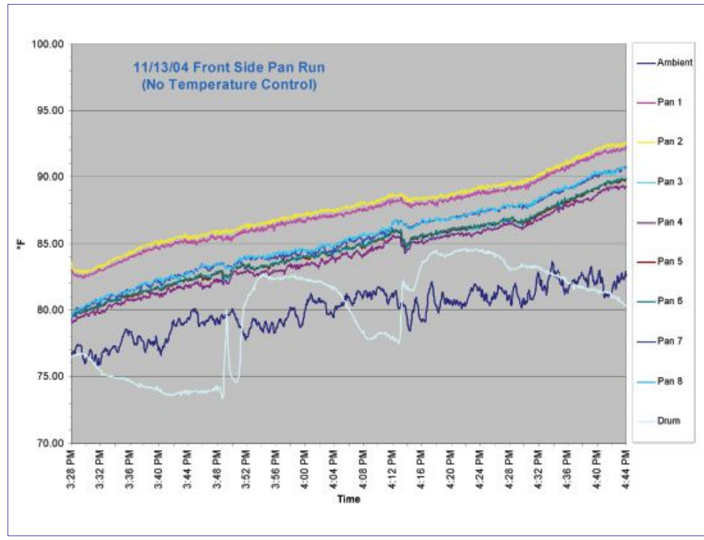

FIGURE 8: *The effect of process friction on temperature*[1]

The heating phenomenon is clearly demonstrated in Figure 8, which shows the temperature profile of a roll coating system without temperature control over an hour's time. Plotted are ambient temperature, drum temperature and the temperature at eight points across the width of the roll. This graph reveals interesting details about the roll coating process. The first is that the process temperature rises 10°F, while ambient rises just 5°F, over the course of this hour. This shows that, because of friction-generated heat, controlling the ambient temperature in the booth cannot accurately control the temperature of the coating.

Previously, we showed the impact temperature has on coating viscosity. Furthermore, the total 4s processing range (26s ±2s) translates to a 5°F window from 80°F to 85°F. Even though the coating was at the 80°F lower limit when the process started, the friction in the system moved the temperature twice the allowable tolerance in just one hour, which will require making other adjustments to compensate for the change in viscosity.

An interesting note from Figure 8 is that the eight points across the face of the pickup roller show a significant variation in temperature. This is depicted more clearly in the "Thermal Profile" display in Figure 9. What we cannot see from this graph is that this uncorrected profile displays continuous variation. What we can see from this graph is that this variation exceeds 7°F at times. This means that the total allowable tolerance is exceeded by variations across the width of the strip. The result is that portions of the coating across the width will always be outside of the viscosity specification. As shown, this can be a sharp change that cannot be compensated for by simply varying the nip pressure from side to side. To assure adequate film build at all points across the width of the strip under these conditions, it often is necessary to increase the total film build, laying down more material than is actually required in some areas to ensure we get the minimum in others.

This effect on film build is demonstrated in Figure 10. Here we can see that the areas of higher temperature result in lower viscosity, which produces a thinner film build, whereas the cooler areas result in higher viscosity and produce a heavier film.

The goal then must be to reduce variations in viscosity as the coating is being applied to the substrate. Unfortunately, identifying and correcting the factors that create viscosity variation at the point of use can be complex and must be treated on a case-by-case basis. It is clear however, this can only be accomplished through the careful manipulation of the flow dynamics in the system as well as the supply temperature of the coating. Figure 11 shows this same system after correction of the thermal profile and the impact on the film build. Here we see that the total temperature variation across the width of the strip has been reduced to about 1°F. This translates to a total edge-to-edge viscosity variation of about 0.8s, or just 20 percent of the total operating window.

Point of Use Temperature Control

In each of these cases, it is clear that the solution to the question of how to stabilize the process lies with controlling the temperature of the coating at the point of application. Though the approach for each is unique, the end result is the same – stabilizing the temperature stabilizes the viscosity and helps to bring the process under control.

It is equally important to accurately control the temperature at the optimal value. Often, with modern UV coatings, that optimal value is exceeded by the ambient temperature. In many cases and in many climates, it is necessary to heat the coating during the cool morning hours and cool it through the warmth of the afternoon. Seasonal temperature variations are even more extreme, but present similar requirements. We also have shown

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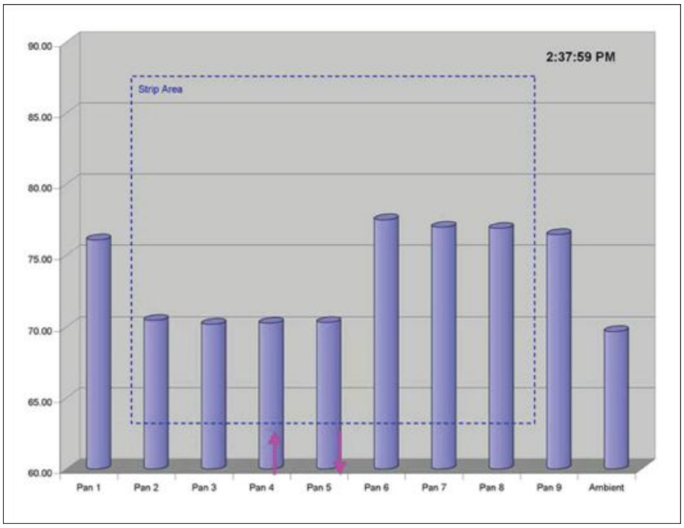

FIGURE 9: *Thermal profile variation*[2]

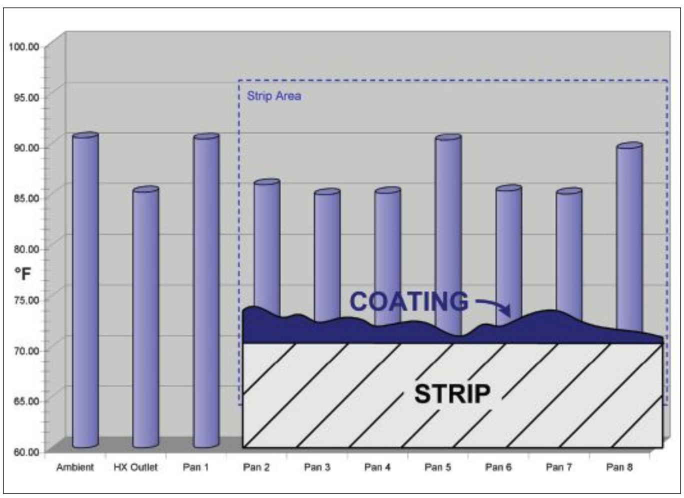

FIGURE 10: *Uncorrected profile and effect on film build*

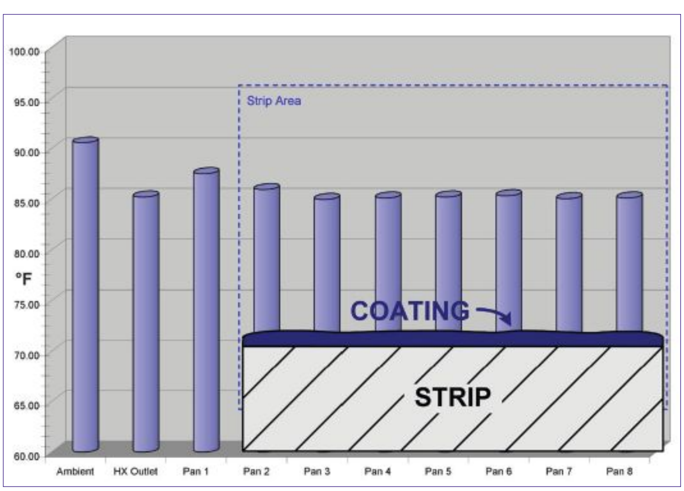

FIGURE 11: *Corrected profile and effect on film build*

that many systems generate friction as a part of the delivery and application process. The friction manifests itself as heat, which must be removed by the temperature control system. In virtually all modern coating applications, a system capable of both heating and cooling – and of switching seamlessly between the two – is essential.

Recent advances in both methodology and thermal transfer devices make temperature a tool that can be utilized to protect the integrity of the coating and optimize the performance of both the coating and the application process. These new and more efficient means move temperature control from the bulk supply at the beginning of the process to the point of application, where it can have a more positive effect on the performance of the coating process. This adds another important parameter to the list of those that combine to control the process, and if the parameters of a proven "coating recipe" can be held constant, the resulting application outcome will be consistent and repeatable.

Conclusion

Though modern UV coatings may be very different chemically from their conventional waterborne and solvent-borne counterparts, the methods employed to dispense and apply them – and their behaviors within those systems – are very similar. This is especially advantageous where modern coating formulations can be substituted for older versions to gain significant performance and/or ecological benefits without incurring major rework, downtime and cost in the conversion. In each case, temperature variations result in viscosity variations that can undermine the advantages of converting. In fact, as shown, the modern coating formulations often are more temperature sensitive than their conventional counterparts.

Modern temperature control systems use innovative approaches and devices to eliminate temperature-based viscosity variations at the point of application and achieve consistent, repeatable performance, independent of changes in ambient temperature and/or processing conditions. This turns temperature from an adversary working against the process into a tool that can be utilized in conjunction with other tools (pressure regulators, speed controls and the like) to assure the coating process outcomes are completely predictable and advance the goals and objectives of the business. ◆

Bibliography

1. The Effect of Process Friction on Temperature data provided courtesy of Alsco Metals Corporation, Roxboro, North Carolina.
2. Roll Coating Thermal Profile data provided courtesy of Alsco Metals Corporation, Ashville, Ohio, utilizing Saint Clair Systems' Profile Analysis and Correction System.

Michael R. Bonner is the vice president of engineering and technology for Saint Clair Systems, Inc., a leading supplier of process temperature control equipment for industrial fluid processing systems. For more information, call 586.336.0700 or visit www.saintclairsystems.com.