Eight Things You Probably Don't Know About the Electric Heaters in Your Fluid Dispensing System

White Paper

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INTRODUCTION

It seems that just about everything from automobiles to water heaters is going electric these days, so you probably think you're on the leading edge because your coating temperature control system is comprised of electric drum blankets and in-line electric heaters. And you did it before it became popular!

Unfortunately, there are little known flaws in this approach that could be causing failures in your fluid dispensing system instead of addressing the problems you set out to solve.

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1

THE PREVAILING LOGIC IS WRONG

The first issue is with the prevailing logic behind this type of system which generally goes something like this:

"If you heat your fluid to a temperature above the hottest day you see in your plant, you will always be operating in the heating mode, so you will always have a constant fluid temperature and therefore a constant viscosity..."

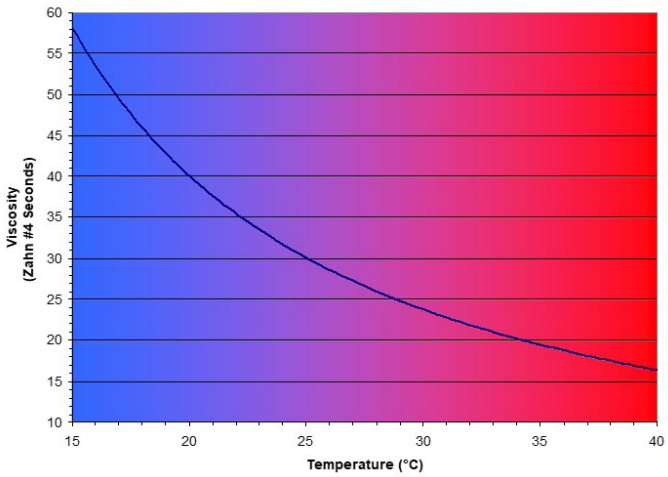

Figure 1: Paint Viscosity vs. Temperature Curve for Valspar 080 White[1]

But there are inherent problems with this logic, and they start with the fundamental behavior of the fluids you are dispensing in the first place. Figure 1 shows the viscosity vs. temperature curve for a common paint. This shows the typical non-linear relationship associated with coatings over the normal ambient temperature range with viscosity falling as the temperature increases. It is this curve from which the prevailing logic for heat-only systems was drawn in the first place, due to the "flattening" observed as the temperature exceeds 35°C (95°F).

By driving the temperature to, or above, 40°C (104°F) our coating is always above the ambient temperature seen year-round (and so always in the heating mode), and also in the flattest portion of the curve where small changes in temperature have the least impact on viscosity. It makes perfect sense…

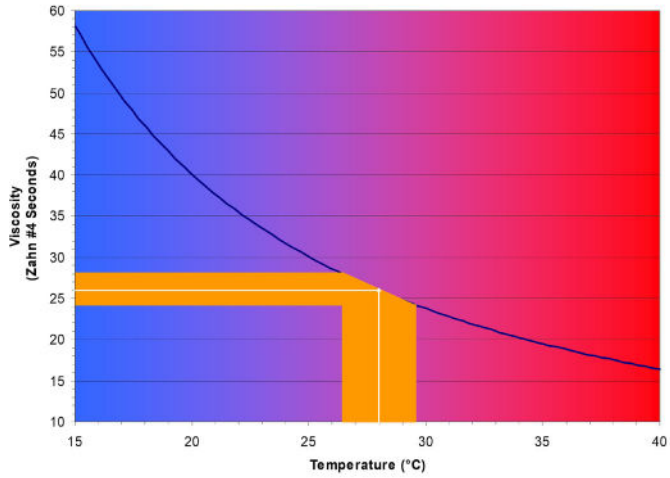

Figure 2: Paint Viscosity vs. Temperature Curve for Valspar 080 White with Target Viscosity Range 1[1]

The problem is that the temperature you need to apply at is the one that produces the optimal film build, coverage, color, adhesion, gloss, finish quality, (i.e. - orange peel), etc. Valspar recommends that this specific paint be applied at a viscosity of 26 ± 2 seconds as shown in Figure 2. We can see that this correlates to a 3°C window from 26.5°C to 29.5°C (80°F – 85°F). If the paint temperature is outside of this narrow window, it will be outside of its optimal viscosity range and performance will suffer.

Driving the temperature above 30°C up results in a low viscosity, which makes it difficult, if not impossible, to build acceptable film thicknesses and coat sharp edges. It also creates flow issues – especially on vertical surfaces – often resulting in run and sag defects.

Elevated temperatures also cause solvents to evaporate more rapidly. This can result in dry spray, reduce flow-out, and set times, which can reduce gloss and increase orange peel. Moreover, it increases cost as

more solvent must be added to counteract the effects of this evaporation. This runs counter to the concept of increasing temperature to reduce the need for solvents in the first place.

Elevated temperatures can even damage sensitive formulations like Fluoropons, PVDF's, Kynars, PVC's and Plastisols, causing them to cross-link prior to application. They can cause 2K materials to cure at an increased rate, reducing flow-out, set time, and pot life.

So, the first thing to know is that the fundamental concept on which your electric heating system is based does not support the needs of your modern coating formulations.

2 ELECTRIC HEATERS CAN'T COOL

An important, but often misunderstood fact regarding viscosity is that every coating formulation has its own temperature/viscosity relationship. Figure 3 shows the plots for seven colors, all the same resin base type and formulated for the same application. But contrary to popular belief, these "identical" coatings display a range of viscosities from 21 to 31 seconds at 25°C (77°F) and each varies quite differently over the 10°C – 35°C (50°F – 95°F) temperature range.

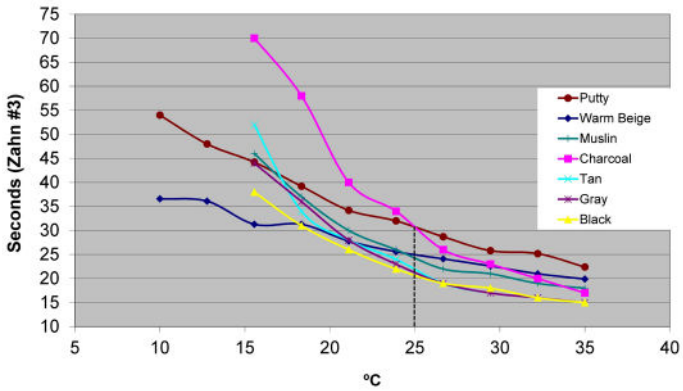

Figure 3: Paint Viscosity vs. Temperature by Color[2]

To obtain acceptable performance from each color, there must be either change in the setup parameters of the application system to compensate for these viscosity variations, or the coating must be consistently delivered to the point-of-application at its optimal temperature.

This is usually somewhere in the middle of the curve (where it is the steepest, of course!) In short, this means that it's necessary to cool when it is hot (like summer afternoons) and heat when it is cool (like nights and winters).

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WHERE YOU PLACE THE HEATER MATTERS

It's commonplace to wrap a heating blanket around the source drum or to place an in-line heater between the pump and the application. It makes sense, as these are easy points of access. But this places too much distance between the heat source and the point-of-application.

Figure 4 shows a thermal model we created for a typical robotic spray system. It allows you to enter a host of variables (Resin Properties and Ambient and Header Temperatures) and see how they impact the temperatures (and therefore the viscosities) throughout the system. But there is only one temperature that ultimately determines the outcome. The point-of-application – as highlighted by the red arrow.

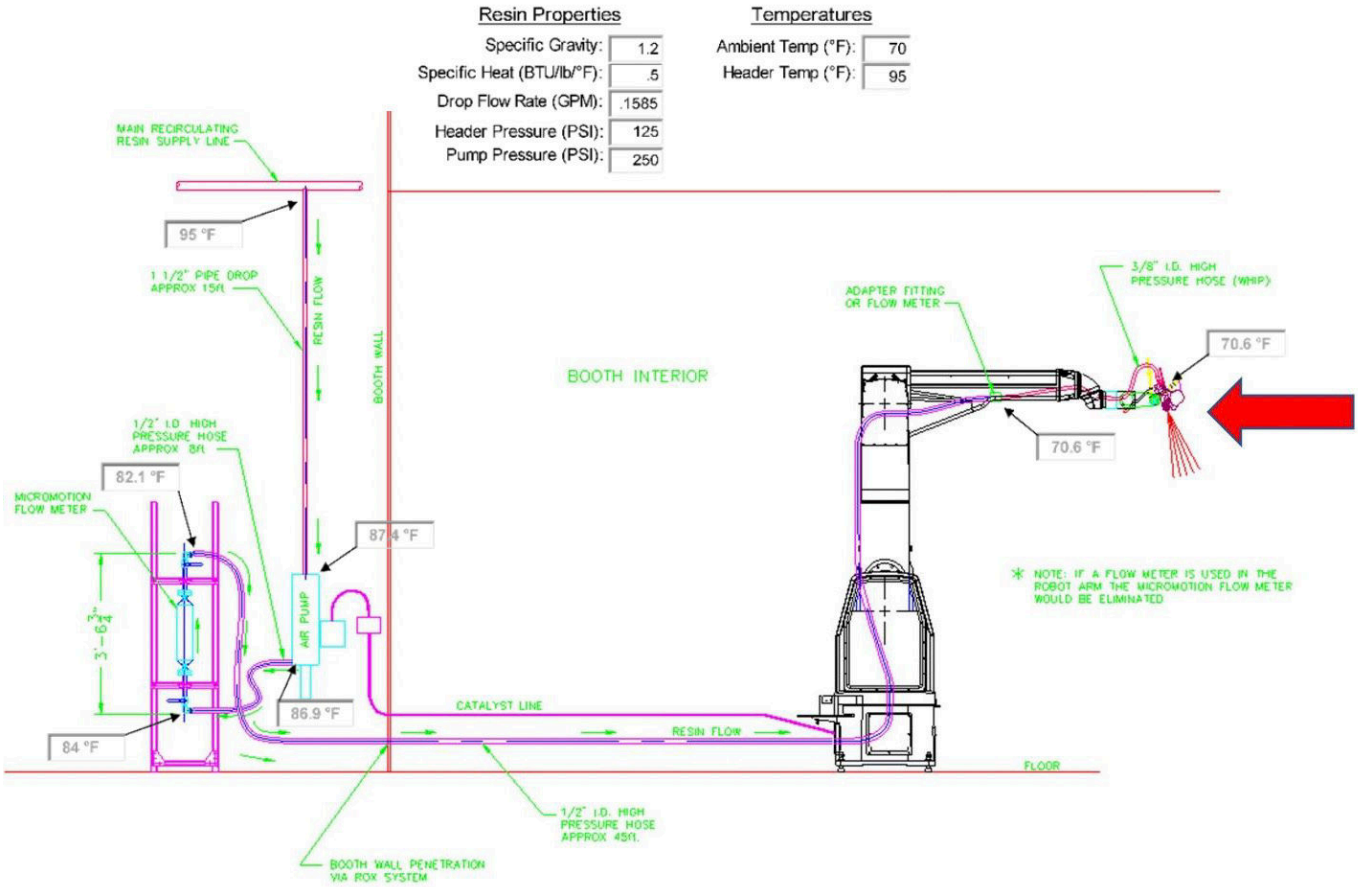

Figure 4: Thermal Model for Typical Spray System[3]

3

WHERE YOU PLACE THE HEATER MATTERS

Let's assume that the in-line heater is in the header just before we reach this drop (it could just as well be right in the drop as it leaves the header – and it often is!)

We can see that it is heating the paint to 95°F (35°C). But we are in a 70°F (21°C) ambient environment so all along the path to the robot, the paint is losing temperature – moving toward ambient. In this instance, the paint comes within 1°F of ambient at 70.6°F.

Figure 5: Inline heaters mounted in an intrinsically safe paint booth[4]. Arrow indicates intrinsically safe wiring.

All the hard work that the heater did (and that you paid for in the form of electricity) was lost by the time that the paint reached the part. It is as if there were no heater in the system at all!

The reason this happens is that the heater needs to be placed too far from the point-of-application. This is because electric heat has high energy requirements which makes it difficult and expensive to implement in explosion-proof environments.

A good example is shown in Figure 5, where two in-line heaters have been installed on a 2K paint system inside the booth using expensive explosion-proof conduit, fittings, etc.

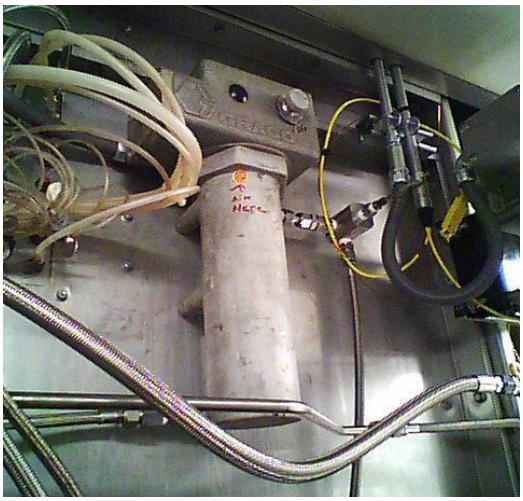

Figure 6: In Line Heater Mounted on Outside of Paint Booth Wall[5].

Another common solution is to mount the in-line heater(s) on the outside of the booth wall where intrinsically safe wiring is not necessary as shown in Figure 6. While this solves the issues and cost associated with the intrinsically safe power wiring, it places the heat source even further from the actual point-of-application.

So, why is this an issue?

4

THE HEATER SETPOINT ISN'T THE APPLICATION TEMPERATURE

As the model above shows, the temperature of the coating when it leaves the heater is not the same as it is when it gets to the point-of-application. But how much it varies is based on multiple factors. Obviously, changes in the ambient temperature from morning-to-evening and season-to-season is the first thing that comes to mind, but the ambient around the path through which the coating travels also changes, depending on both the routing that the piping follows and the materials in that path.

For instance, if the path is "up and over" running in the truss level, it will be exposed to higher temperatures. Conversely, if it is routed through a trench or basement, it will be exposed to cooler temperatures. And the impact of those temperatures is determined by the composition of the coating path components. For instance, is the path comprised of steel tubing or hoses? Is it insulated? Everywhere? Including the fittings, filters, regulators, flow meters, etc.?

Then there's the question of how many times the coating is exposed to these conditions. Does it flow direct to the robot and stop in a dead-end configuration, or does it recirculate? And if it is recirculating, does it recirculate at the robot or just to the drop? This determines how long the coating can sit in the ambient surroundings before it is applied – an important factor in determining the temperature (and therefore the viscosity) when it is applied.

5

VISCOSITY VARIATIONS AFFECT YOUR SPRAY PATTERN

In spray application systems, temperature-based viscosity variations directly affect the shape and integrity of the fan pattern being dispensed. As proof, Figure 7 shows the results of a controlled experiment in which a robotic system was used to repeat the gun path, speed, angle, and distance to spray each of the coupons with a fixed orifice gun under constant pressure. The only thing that was varied was the temperature of the coating, which, of course changed its viscosity as it was sent to the nozzle.

The most obvious change is in the width of the fan pattern. But perhaps less obvious, yet even more important, is the impact of viscosity on spray consistency.

Above 35°C (left two coupons), the coating is thin and uneven. You can see the substrate peeking through. Even if it adheres well, it can't do its job. By contrast, in the 30°C to 35°C range the fan pattern is stable, and the coating is smooth from edge to edge. This is the optimal operating temperature (read: viscosity) for this process.

Below 30°C (due to the increased viscosity) we see heavy edges beginning to appear. These are often associated with "striping" and uneven coating on the finished part. And continuing into the 25°C range and below, we see the combination of very uneven coating surrounded by heavy edges which makes it virtually impossible to get a smooth, even coating on the finished part – whether you're painting manually or with a robot. Without a smooth, even coating, both performance and appearance will be compromised.

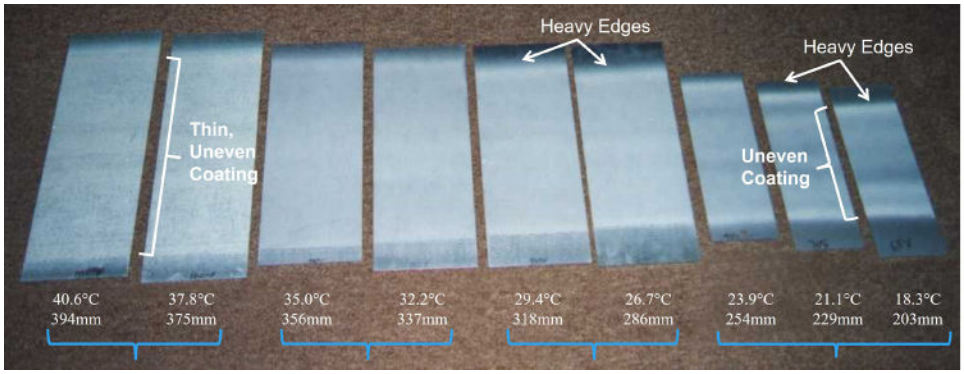

Figure 7: Impact of temperature based viscosity variations on spray pattern[6].

6

GAPS IN THE SYSTEM CREATE UNPREDICTABILITY

As if spray consistency wasn't enough, the importance of this behavior becomes even more apparent when we examine the impact of gaps in our 90°F temperature control envelope that allow ambient to affect our coating material. Figure 8 shows the effect of a 73°F ambient on a stainless-steel gun, when the spray stops – like during a break, or lunch or downtime event. It's OK when we are processing and the material is in constant motion, but when we stop, the valve acts like a heat exchanger pulling energy from the material and exchanging it with ambient so the temperature of the material falls and the viscosity of the material increases, which drives a change in spray pattern as we saw in the coupons in Figure 7.

Figure 9 shows the impact that this change in temperature (and in turn viscosity) has on the dispense pattern, which can be completely anticipated from Figure 7. As the colder material in the gun is dispensed, the pattern is narrower and heavier, but as the warmer material reaches the gun, the lower viscosity causes the pattern to widen and the film to thin. This could just as easily have been a fitting anywhere in the delivery train creating a slug of off-viscosity material and creating a defect that may, or may not, get caught.

This is just one of the reasons that distance between the heat source and the applicator nozzle is of utmost importance to our process outcomes.

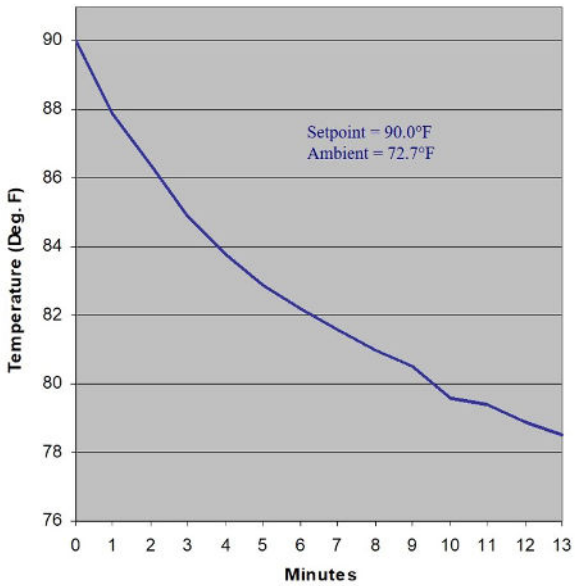

Figure 8: Impact of ambient on gun temperature when flow stops[7].

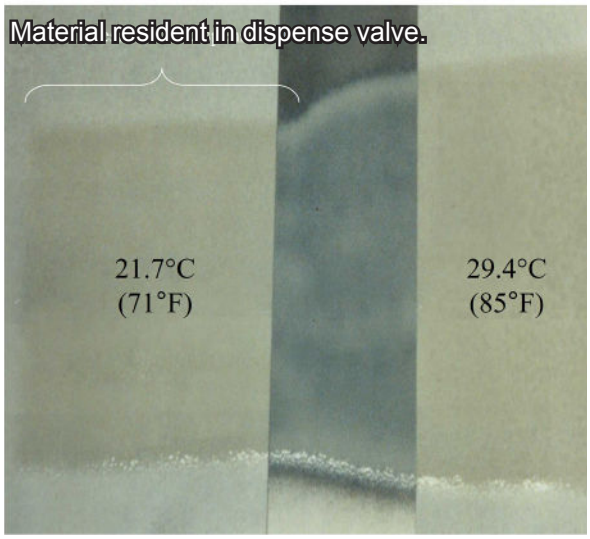

Figure 9: Impact of ambient temperature on spray pattern[7].

7

Remote Heating Dissipates Faster Than You Think

So, by now you may have already asked yourself, “Does the temperature of my coating really change as fast as the model in Figure 4 predicts?” For a couple of good examples, let’s dive a little deeper into the applications shown in Figures 5 and 6.

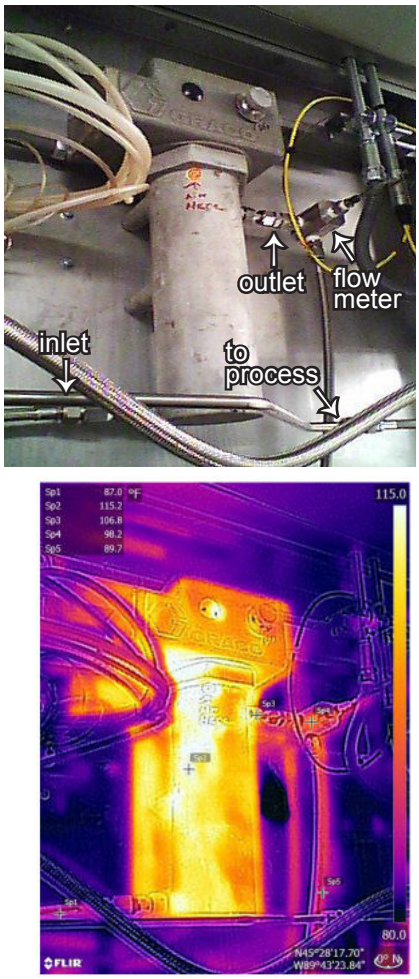

Figure 10: Thermal scan of heater on outside of booth wall[5].

In Figure 10, the top frame shows the heater on the outside of the booth wall as shown in Figure 6 with the thermal scan in the lower frame. There is much to be observed in the thermal scan.

The inlet hose in the lower left corner shows that the coating is coming in at about 87°F (Sp1), and by the time it leaves the 115°F heater (Sp2) it is up to nearly 107°F (Sp3). All good so far, but this is where devices in the path and the effect of ambient comes into play. We know (from the scale) that the ambient is approximately 80°F.

The surface area and thermal mass of the flow meter are the first things the coating encounters. Here we see it drop to roughly 98°F (Sp4), and as it travels through the hose toward the booth interior it drops further to roughly 90°F (Sp5).

Since thermal imaging shows surface temperatures, the actual coating temperature at each of these points will be higher than the reading shown. The relative magnitude of the change, however, will be exactly as indicated.

Figure 11 shows thermal scans of the 2K system shown in Figure 5 above. In the legend we can see that the A & B coating components are entering the heaters at roughly 75°F (Sp1 and Sp5).

Figure 11: Thermal scan of 2K system inside of booth[4].

This makes sense in that they are both coming from the same ambient location, which is carefully controlled at 75°F. It is here that things run amuck. From the color it is clear that the left heater (Part B), at 179°F (Sp2), is significantly warmer than the right heater (Part A) at 103°F (Sp6). As expected, the outlet of Part B is about 99°F (Sp3) whereas the outlet of Part A is 87°F (Sp7).

Again, we see the coating components losing temperature as they move through the hoses with Part B at 93°F (Sp4) and Part A at 85°F (Sp8) roughly equidistant from each heater.

As shown in Figure 12, this loss continues along the path through the booth ambient with Part B at 87°F (Sp4) and Part A at 82.5°F (Sp5). These are getting closer to the ambient temperature, and the difference between them is shrinking due to the different rate of loss based on the temperature differential to ambient for each component.

As with the previous example, the coating components are reaching the robot very near ambient – again, as if there were no heaters in the circuit at all.

These examples suggest that the model in Figure 4 is reasonably accurate.

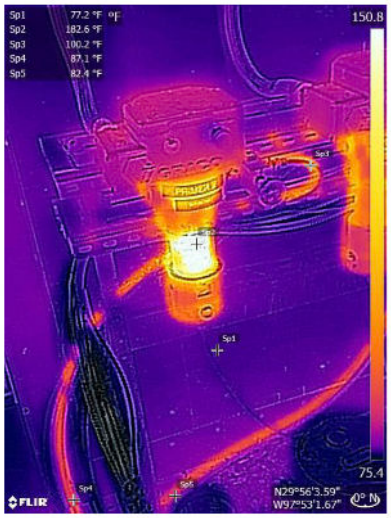

Figure 12: Thermal losses of 2K system along the fluid path[4].

8

ELECTRIC HEATING CAN ACTUALLY DAMAGE YOUR EXPENSIVE COATING

But worst of all is the little-known fact that, in the process of bringing the coating to the target temperature, electric heaters they can actually damage the coating before it is even applied.

So how can a device designed to help with the process do damage?

The answer is “surface area”. An electric heater is basically a heat exchanger and there are two important factors that determine the magnitude of heat transfer – surface area and temperature differential, which is also referred to as “Delta T (ΔT). Because in-line electric heaters have a very small surface area in contact with the coating, they must get very hot to heat the coating to the desired temperature – as shown in Figures 10 and 11. The contact of the coating with these hot surfaces can damage the coating causing premature cross-linking, chemical separation, etc. This can result in agglomeration that clogs nozzles and filters, curing issues, poor adhesion, unacceptable appearance, and a host of other problems.

CONCLUSION

It’s clear that, though common in their implementation, there are many issues with in-line electric heaters that must be understood and managed if you are going to get stable, predictable performance out of your coating application system.

BIBLIOGRAPHY

1 – Paint Temperature vs. Viscosity data provided courtesy of Alsco Metals Corporation – Roxboro, NC.
2 – Paint Viscosity vs. Temperature data provided courtesy of Sherwin-Williams Corporation.
3 – Spray System Thermal Model provided courtesy of Saint Clair Systems, Inc.
4 – Electrically Heated 2K Paint System Photos courtesy of CFAN – San Marcos, TX. (Note: This has since been replaced with a modern heat/cool system.)
5 – Source withheld by request.
6 – Impact of Temperature Based Viscosity Variations on Spray Pattern data provided courtesy of Saint Clair Systems, Inc.
7 – Impact of Ambient on Gun Temperature and Spray Pattern data provided courtesy of Saint Clair Systems, Inc.