Computer Modeling in Today's Converting World

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As a manufacturer of custom dryers and ovens, our daily challenge is to come up with the best design, utilizing the latest technology to solve a customer's drying needs. This encompasses many different substrates (paper, PET, PP, foils), solvents (water, toluene, MEK, ethyl acetate, acetone, to name a few), products (silicone release, window film, PSA's, etc.). If you are a converter, you already get the picture. Our job as a manufacturer is to combine these parameters and come up with the design that will not only be successful, but also be the most cost effective at the same time. And it has to be done the first time!

Computer simulation of the drying process is critical to the overall design scheme for optimal use of floor space, energy consumption, and production speeds. This paper will look at a few examples of how computer modeling can be utilized to improve these designs, as well as what information dryer manufactures really need in order to come up with a dryer that truly meets the customer's needs.

The drying process can be broken down into two components – mass transfer and heat transfer. Computer modeling looks at the best way to achieve both mass and heat transfer.

> **Mass transfer** (the vaporization of solvents in the coating) is a function of the differential of the partial pressure between the solvent in the coating and the solvent in the surrounding air.
>
> **Heat transfer** (the exchange of thermal energy) is a function of the differential of the heated turbulent supply air and the temperature of the web, coating and solvent.

The primary factors that affect drying are the supply temperature, the nozzle velocity, the supply volume, the proximity of the nozzle or air bar to the web, and the pitch, the center to center distance of the nozzles.

The first things to consider when working with computer modeling are the process variables – the substrate composition as well as the weight or thickness; the dry and/or wet coating weight, solvent – water or another solvent such as MEK, Toluene or another volatile; coating percent solids; production speeds, and any restrictions to the process, such as a web temperature or evaporation rate limit. The more information we are given, the more accurate the modeling and subsequent proposal will be.

Once this information has been compiled, the next step is to review the parameters and determine the best air delivery device, based on our experience and the customer's preference. The two most common styles of dryers are roll support or flotation. Each has its own positives and negatives, and there can be a wide variety of nozzle configurations with both styles. Air bars, or nozzles, are designed for different applications, and when they are incorporated into a dryer have different heat transfer characteristics, or “H” factors. While the nozzle itself doesn’t have the “H” factor, the way it is utilized within the dryer provides the overall “H” factor. This goes back to the nozzle pitch, proximity to web, supply temperature and nozzle velocity.

In Figure 1, below, the roll support dryer is illustrated. With this dryer, the impingement air generally comes from the top side only. The spacing, or pitch, between the nozzles can vary, as can the proximity between the nozzle and the web. Typically, this nozzle-to-web distance is 50-100 mm. In addition to these variables, the nozzle opening itself can be changed. The more open the gap, generally the velocity of the air exiting the nozzle is reduced. Conversely, as the gap is closed, the impingement force increases. In some respects, this can be viewed as “brute force drying.”

Roll Support Example

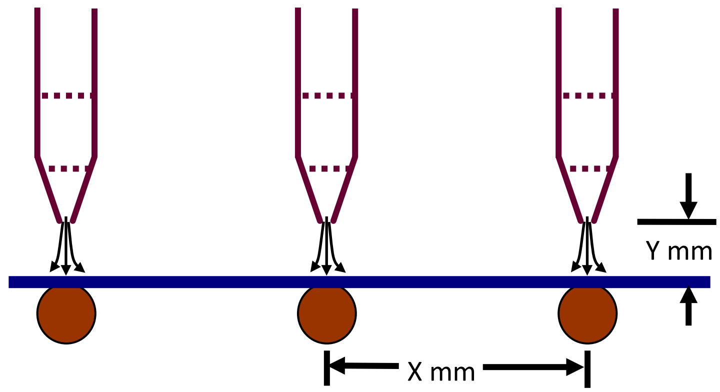

Figure 1

Figure 2 is an illustration of flotation drying. In this case the web literally floats through the dryer on cushions of air that are created by the air bars. This style of drying provides much greater heat transfer because the web is heated from both sides, and the proximity between the nozzles and the web is much closer, typically 9.5mm. In most applications, the nozzle pitch is 25 – 38 cm.

Flotation Example

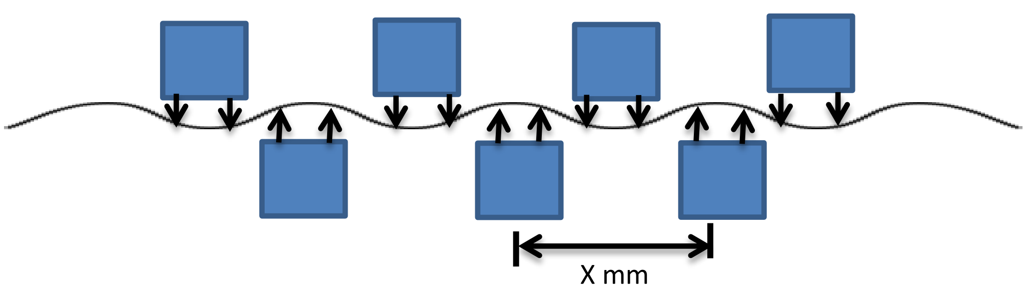

Figure 2

To illustrate this further we can look at the following comparison between a roll-support dryer and a flotation dryer. Given the same product Figure 3 below offers a side by side comparison of the two different dryer types. In this example, this is the coating parameter: 94 cm wide 50 micron PET, 305 mpm production speed, 2 gsm dry coat, 5% solids with a water based coating.

DRYER COMPARISON

	Effective Length	Pitch	Projection	Air Temp	Nozzle Velocity	Fan Power	Heat Load	Exit Web	Supply Volume
DRYER	(mt)	(cm)	(cm)	°C	Mt/sec	Kw/zone	MJ/hr	°C	Standard mt^3 /min
Roll Support	17.7	19	5.1	315	30.5	14.0	5800	95.8	170/zone
Flotation	12.9	38	0.6	315	33.0	11.5	4850	104.9	130/zone

Figure 3

While both dryers are two zones in length, the flotation dryer is nearly five (5) meters shorter than the roll-support dryer, uses less energy, both from the supply fans and the burners. Because the projection is less, and the nozzle velocity is higher this arrangement is able to offset the reduced pitch of the roll support dryers, and has a higher “h” factor.

As illustrated in the photo below, there are many different styles of air bars or nozzles that are available for use, based on the appropriate application. If this is a very specialized application, it’s possible that a new nozzle may have to be developed.

Photo 1

Dryer manufacturers are typically given a product range of web weights, coating weights and solids percentages. While it is unusual that any manufacturer today has the luxury of only making one product, it is helpful to narrow the process window as much as posible. It would be helpful if the design parameters supplied by the customers would cover the majority their needs, say 80% of the desired product range. This would come with the realization that some products could be run at higher speeds, and others would have to run more slowly.

If a dryer manufacturer is given a product range, they will normally opt for a "Worst Case" scenario. To simplify the process, only one variable will have a range, the coat weight with a range of 5-10 gsm.

Web Width: 1.5 mts	Production Speed: 300 mpm
Coating % Solids: 15	Substrates: Paper 150 gsm
Solvent: MEK, Toluene, IPA	Dry Coat Weight: ***5-10 gsm***

For the first computer simulation, the 5 gsm coat weight was chosen. Based on this coating information, we came up with a three zone dryer, with each zone being nine meters in length. Since there are high volumes of solvents, care had to be taken to not exceed the safe Lower Flammable Levels (LFL) in the exhaust stream. In this instance, the LFL was the driving factor of how quickly we could evaporate the solvent in the product.

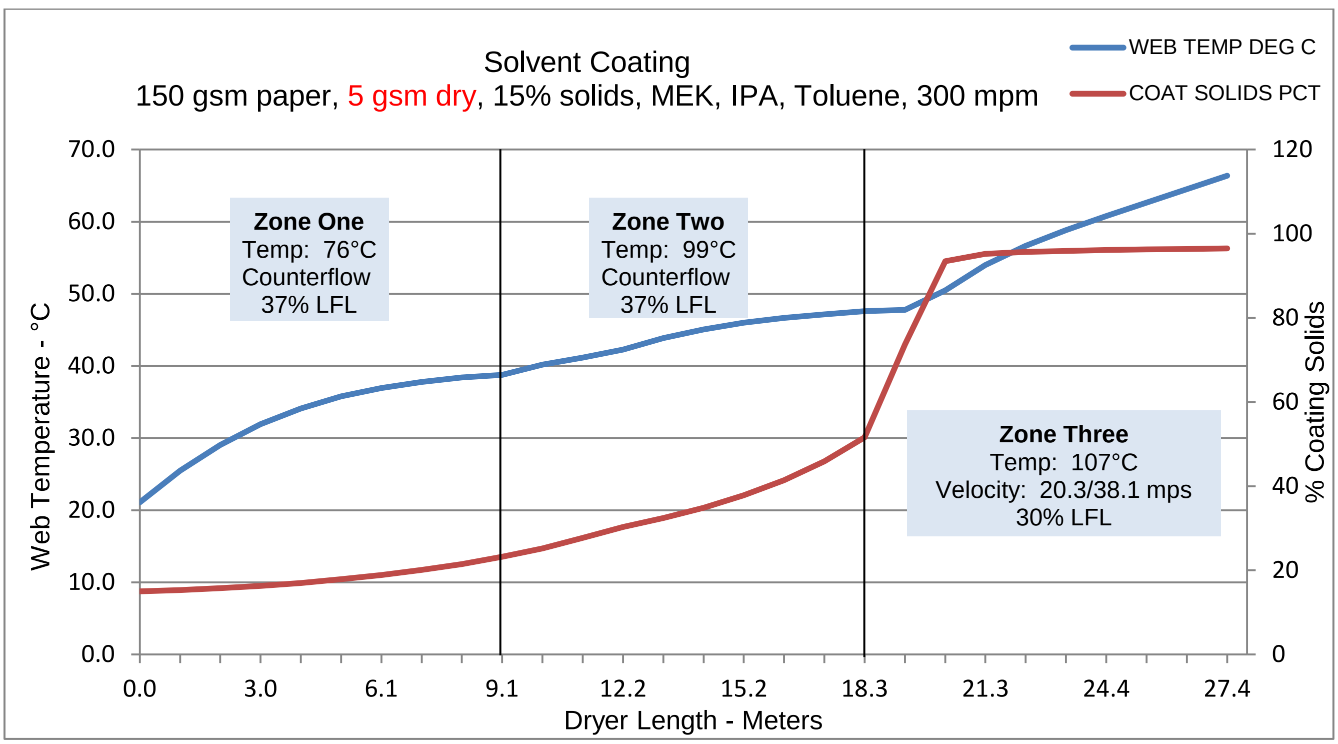

Figure 4

The second simulation was done using a dry coat weight of 10 gsm. While the doubling of the solvent didn't result in a doubling of the dryer length, two additional nine meter zones were required. This provides a quick illustration of how a dryer can become quite long if assumptions about the process are made. this added length obviously impacts the footprint and cost. In addition, it also affects the RTO or pollution control sizing. It's quite possible that the converter is aware that they would have to run this product at a much lower speed, but the manufacture still has to design for the most challenging situation.

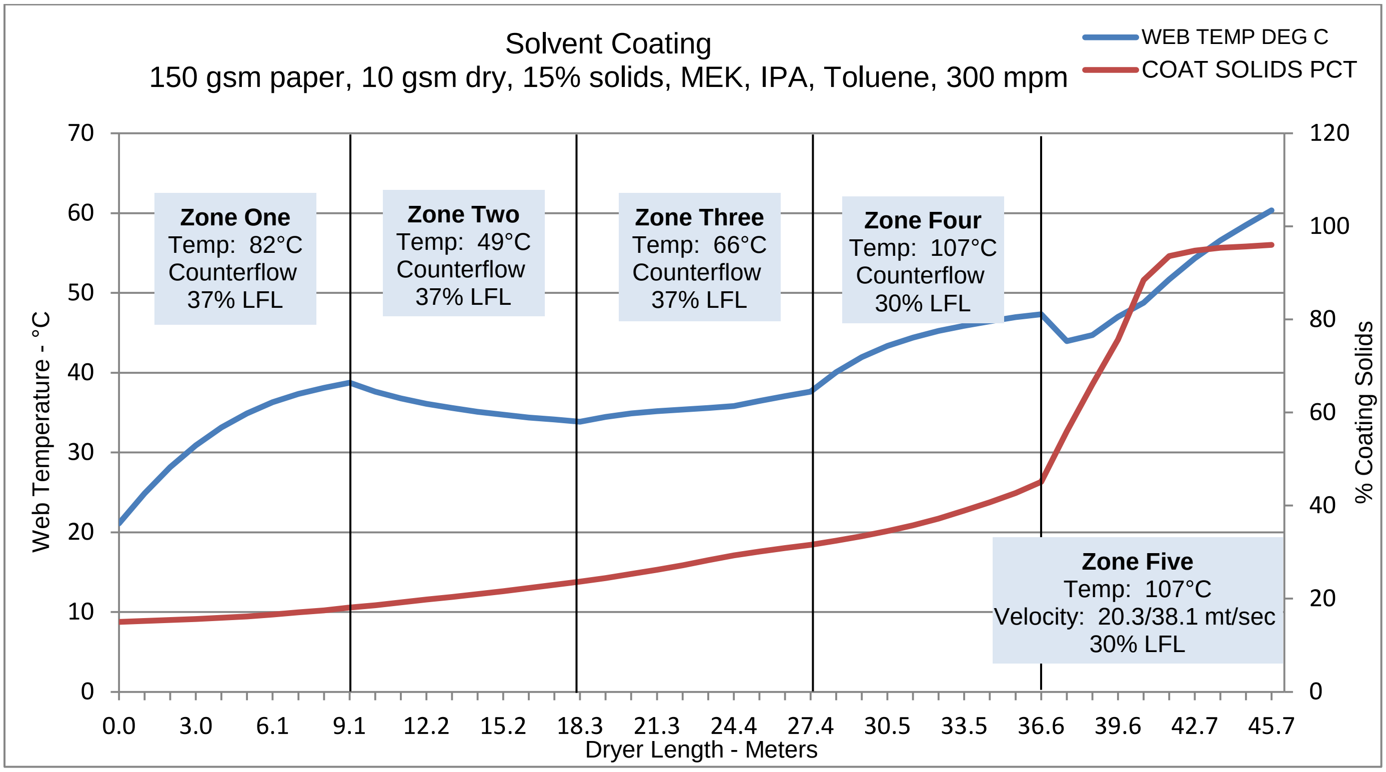

Figure 5

It is also quite common for dryer manufacturers to receive wide ranges of web weights (100 – 200 gsm), thickness (12-100 microns), coat weights (1-20 gsm), solvent mixtures, various production speeds, etc. This is why it is critical to have a good understanding of the process data, so there will be no major surprises at a later date.

Computer modeling also enables the manufacturer to customize a dryer for a specific application. For example, instead of making a standardized zone length, say 3 meters or 5 meters, computer simulation permits the manufacturer to review the drying curve and optimize the dryer length the number of zones.

In the case of a high speed silicone coating application where curing is involved in the process, and multiple zones will be required, having the ability to customize zone lengths can be a real money saver.

Because silicone needs to be cured, the goal is to get the web to the desired cure temperature as quickly as possible and start the cure process. Once the web has achieved this temperature, it is relatively simple to maintain the temperature. The advantage of multiple zones is that the customer has more flexibility in changing the temperature of the supply air so it can be modified to maximize throughput, while minimizing energy costs. However, since temperature remains constant during the curing phase, changing the number or length of zones has no impact on the process, but it can have significant impact on the overall cost of the dryer. If even one plenum, and all of the instrumentation associated with it can be eliminated, the resulting savings would be in the thousands of Euros.

In the example below, the web was elevated to the cure temperature in the first two zones, each 4.9 mts long. The curing was done with air foils spaced on a much wider pitch than normal, in zones that were 7 meters in length. If standard zones, for example five meters in length, were used, this layout design would not have been available, and an additional zone would have been required.

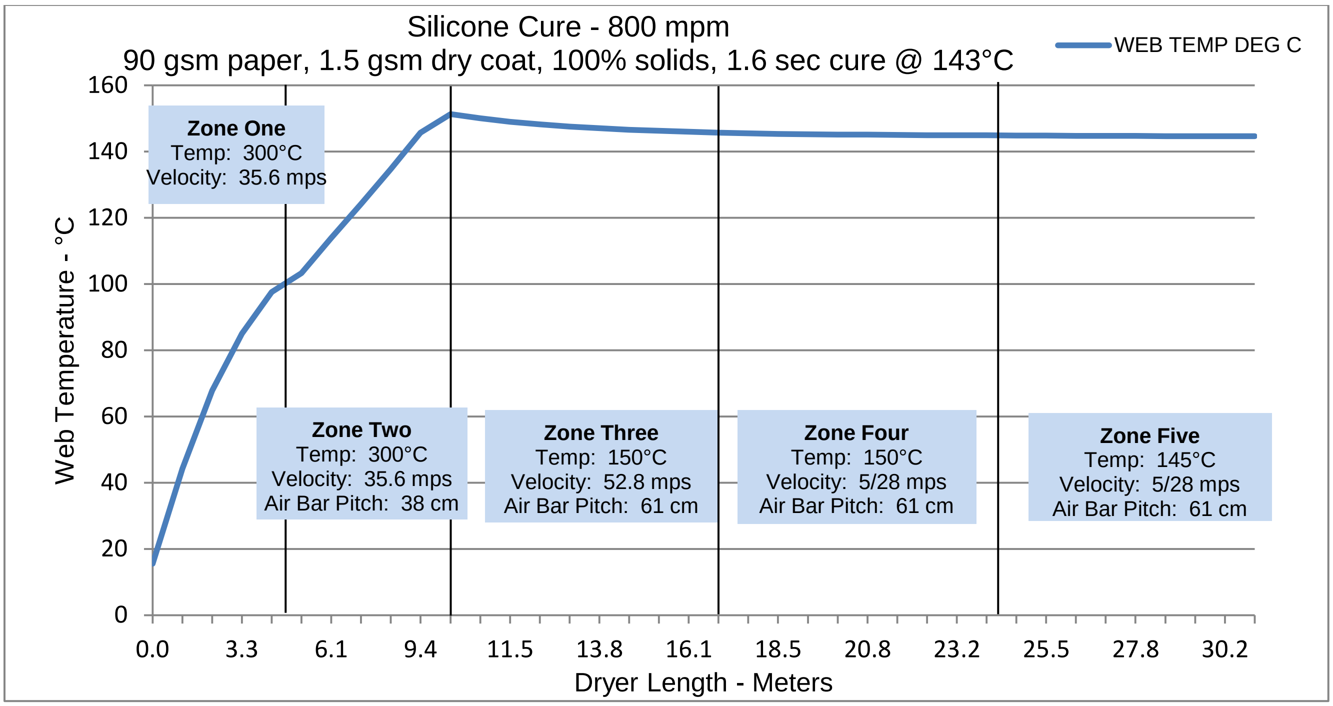

Figure 6

Multiple zones are important with silicone curing applications. As illustrated in Figure 7 below, a single zone application, the temperature of the supply air results in a much hotter web than is required. Since there is no evaporative cooling associated with silicone curing, the web temperature will more quickly reach the supply temperature. This results in needless energy waste, in addition to the possibility of damaging the substrate. The elevated web temperature also requires additional cooling, should it be necessary prior to the next production process.

The only way to avoid the overheating of the substrate would be to reduce the supply temperature and, as a consequence, the production speed at the same time. This would push the temperature curve to the right, and the “cure length” would also shorten.

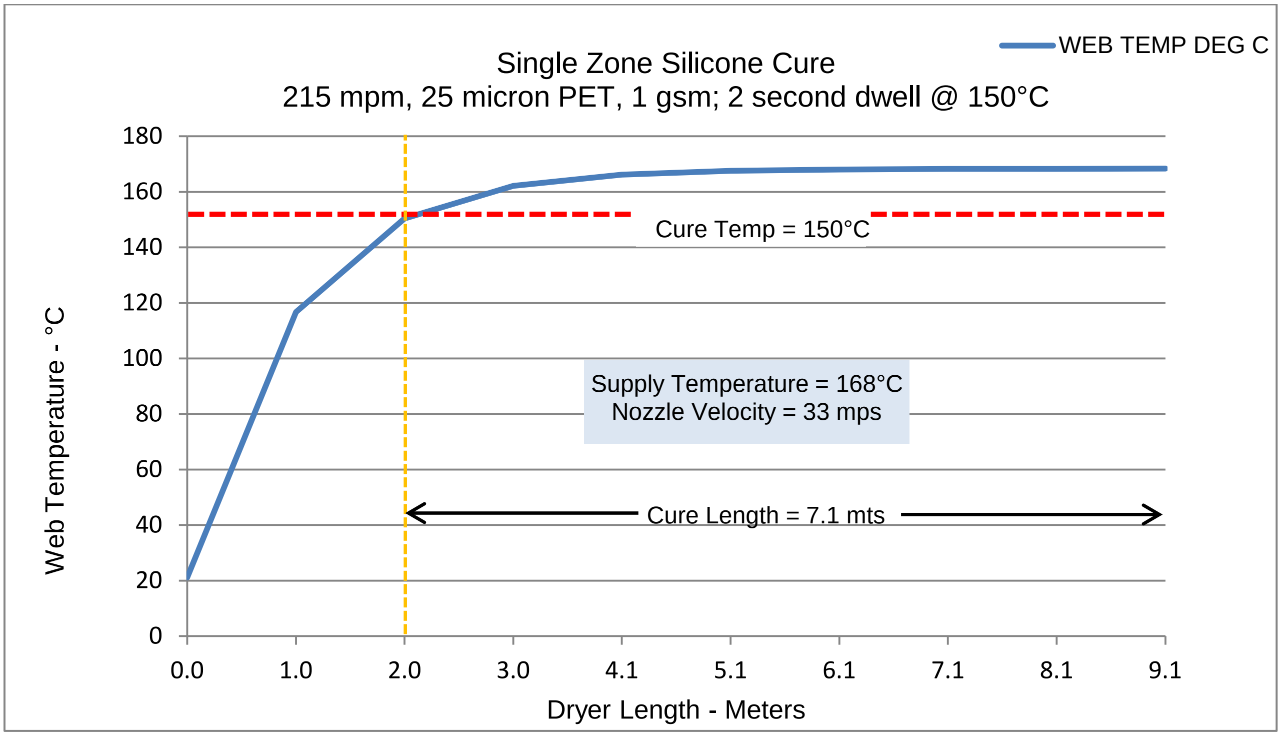

Figure 7

The preferred method would be to have a shorter first zone which will enable the use of higher temperature supply air to get the web to the cure temperature quickly, and then start the cure in the next zone.

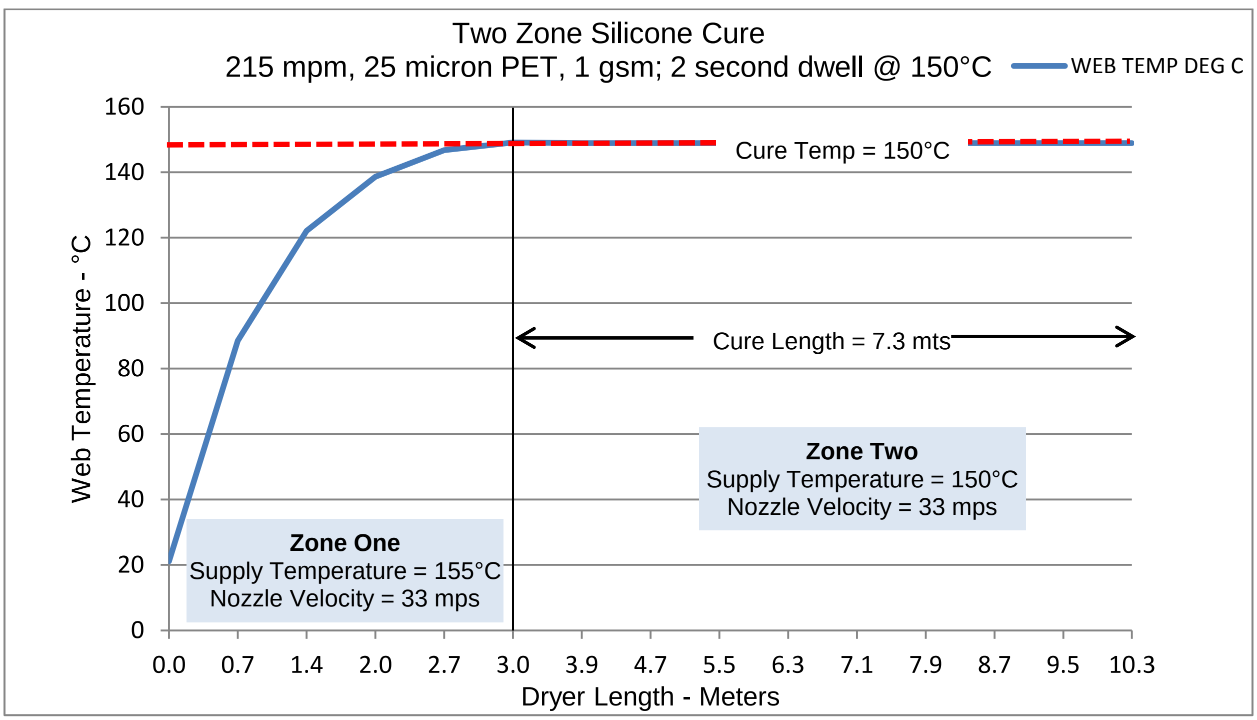

Figure 8

This provides more flexibility in the production, enables the converter to achieve the proper temperature to avoid product deformation, and can result in a more efficient process. IR sensors can be added to the dryer to indicate where the cure temperature is achieved, so cure can be proven.

To summarize, computer modeling is an invaluable way for both customers and manufacturers to design and develop dryers that will work effectively and do the job that is expected. Computer modeling can be used from the beginning of a project, at the budgeting phase, to get an idea of how fast a product can be coated, making it easier to justify a project. Modeling can also provide some operating parameters for exhaust volumes that would be required for pollution control systems.

The best way for all of us to succeed is to have as much specific information as possible as it pertains to the process:

Web Information	Coating Information	Process Limitations
Material	Wet or Dry Coat Weight	Evaporation Rate Limit
Thickness	% Coating Solids	Web Temp Limit
Width	Solvents	Coating Temp Limit
Desired Speed		

The dryer may be a “necessary evil” in the coating line, but it is certainly one that can make or break the success of the line. The right information and the right modeling go a long way with starting this process. The converter doesn’t want to spend money needlessly on extra length to ensure that the line works. Likewise, they don’t want to purchase a dryer that’s too short, since that also leaves them short on productivity. Computer modeling is a great way to make sure that the size and scope of the dryer matches the customers’ needs, and it really is dependent on the sharing of information. The more that is known, the more accurate, and better the project will be.