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- Unique Demands of Small Lots In Coil Coating Operations
- On-Line Wet Film Measurement
- ASTM D01.53

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Some of the coating heads have shown that the best thermal profiles (those with the smallest edge-to-edge temperature variation) are found on heads operating in a 3-roll reverse (indirect) nip-feed coating configuration.

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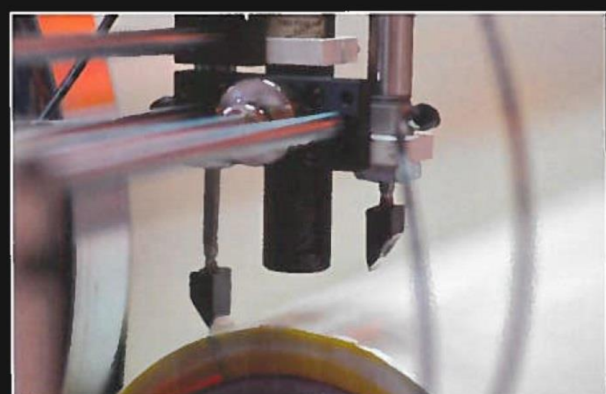

Measurement head showing the safe sensor and automatic Low Pressure Blades.

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Coil coating expertise.

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Addressing the Unique Demands of Small Lots in Coil Coating Operations

By Michael Bonner, Vice President, Engineering & Technology, St.Clair Systems, Inc.

In the article "Minimizing Cleaning Costs in Modern Coil Coating Operations", which appeared in Coil World's September/October 2012 issue, we noted: "*...the coil coating marketplace has changed significantly. Extreme economic pressures have resulted in a great deal of consolidation within the industry, and some coaters have failed entirely. Those that remain live in a significantly different competitive environment. Nowhere is this more evident than with toll coaters. Gone are the days of the 72-hour run. Customers are striving for leaner operations with lower inventories. As a result, they are demanding smaller, more frequent shipments with shorter leadtimes. Faced with the same business constraints, coaters are being forced into shorter runs – often just a portion of a coil...*"[1]

In fact, this has become the norm in the industry for virtually all coaters, resulting in operational issues which include:

- more frequent color changes
- more partial drums to handle and store
- increased cleaning costs
- increased setups and quality checks
- reduced available run time

These issues drive reduced efficiency at a time when excess production capacity in the marketplace is forcing razor-thin margins, and they require innovative strategies if a coater is to remain viable.

Improving Efficiencies

There are many ways that coaters can improve their efficiency. That particular article compared various cleaning methodologies, analyzing them to identify the most time efficient and cost effective option available to the coil coater. Moreover, the introduction of simple, non-intrusive, effective point-of-application temperature control in 2005 has enabled many coaters to also realize gains by:

- reducing solvent additions
- reducing paint consumption
- improving film quality and appearance
- improving batch-to-batch repeatability

So how has the addition of temperature control enabled forward-thinking coaters to realize all of these benefits? The answer lies in the relationship between temperature and viscosity and the relationship between viscosity and film.

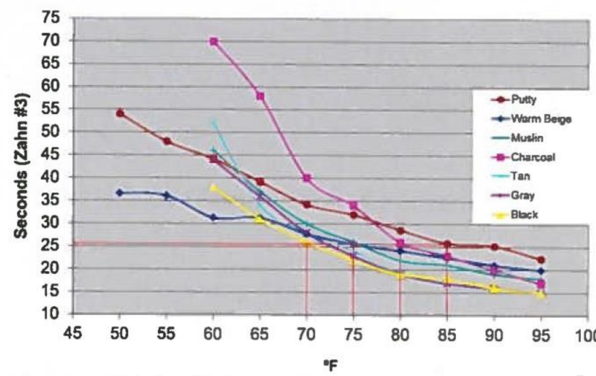


Figure 1: Relationship between Paint Viscosity and Temperature[3]

Temperature, Viscosity, and Film

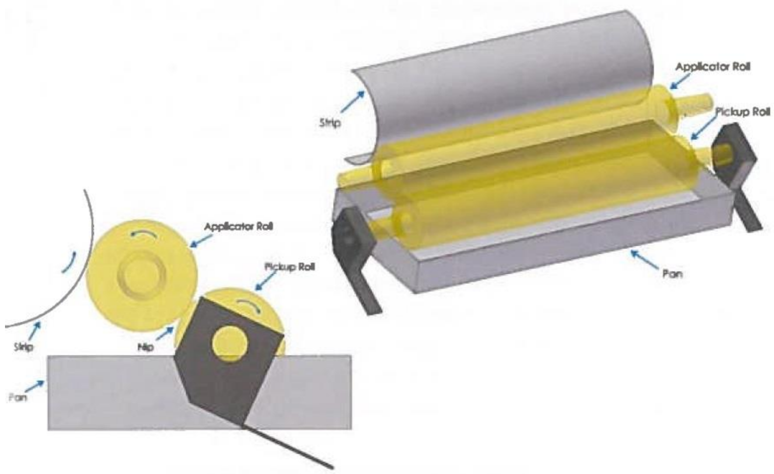
"*...all coaters understand the importance of fluid viscosity to the coating process. Performance parameters such as coating film build, color match, voids, chemical resistance and the like can all be linked directly to the viscosity of the [liquid] coating material when it was applied. In addition, process parameters such as pressure, flow rate and coating speed are all dependent on coating material viscosity. For these reasons, virtually all coating processes begin with the measurement and/or adjustment of coating viscosity.*"[2]

Given this understanding, it is common for a coater to adopt a policy of running similar coatings at the same viscosity in an attempt to stabilize other process parameters, like roll speeds and nip pressure, thus simplifying setups and increasing the efficiency of color changes.

Unfortunately, what's often misunderstood is that this relationship varies for each color formulation – even within the same paint type. Figure 1 shows the Viscosity vs. Temperature curves for a group of related paint colors. These are all of the same resin base type, yet they display very different viscosity characteristics as a function of temperature. As demonstrated in the May/June 2012 Coil World article "Adjusting Coating Viscosity" quoted above, if all of these colors are to be run at a 26-second viscosity and the temperature is below 70°F, all will require viscosity reduction – likely through the addition of solvent – in order to reach that 26-second target. As the topic of solvent addition is covered in depth in that article, suffice it to say here that the addition of solvent runs counter to the efficiency and cost-containment objectives of coaters in today's marketplace. As a result, many have turned to temperature control as a means of controlling viscosity. In the example shown in Figure 1, if a constant 26-second viscosity is desired, the Black must be run at 70°F, the Muslin and Warm Beige must be run at 75°F, the Charcoal must be run at 80°F, and the Putty must be run at 85°F. This produces a consistent viscosity across all colors without the time and cost of adding solvent, which is ultimately "burned-off" in the curing process anyway.

Another issue is the significant friction that is generated in the roll coating process. This adds energy to the paint and causes its temperature to vary widely. Figure 2 below shows a typical 2-roll reverse (indirect) coating configuration:

Figure 2: Typical 2-Roll Reverse (Indirect) Coating Configuration



Here, the coating is picked up from the pan by the pickup roll, and then transferred to the applicator roll, which in turn, applies it to the passing strip. The pickup roll has a hard surface, usually constructed of steel and sometimes ceramic coated. The applicator roll has a compressible surface, usually constructed of steel with a thick urethane (or other polymer) coating. These two rolls are forced together at the "nip" under significant pressure, often in the 2,000 – 3,000 PSI range. When the pickup roll carries the coating from the pan to the nip, it is squeezed down so a thin film remains on the applicator roll to be applied to the strip. That film thickness is determined by the pressure between the rolls at the nip, the durometer (firmness) of the urethane applicator roll, and the viscosity of the coating. The balance of the coating on the pickup roll is sheared away by the action of the nip and falls back into the pan.
The texture of the pickup and applicator roll surfaces and the pressure between them results in a great deal of friction, which generates heat. Additionally, as the coating is applied, the friction between the applicator roll and the strip, which is intensified by their opposing directions of travel, also generates heat. Much of the heat generated by this process is carried back to the pan, first by the coating squeezed out of the nip, and then by the pickup roll, which is submersed in the coating in the pan.

The flow of coating in the pan is determined by numerous factors, including the geometry and volume of the pan itself, the rate at which the coating is being pumped into the pan, the location of the inlet, the location of the outlet, the speed of the pickup roll, and the rate of coating usage – but the flow is almost never directly from the inlet to the outlet. Because of all the rotational vectors generated by the various motions in the system, significant swirls and eddy currents are spawned in the coating. As such, the heat produced is unevenly distributed throughout the pan. Saint Clair Systems has developed specialized methods for measuring the resulting temperatures at multiple points throughout the application system, and these measurements have repeatedly shown that significant temperature variations are presented to the nip along the width of the strip.

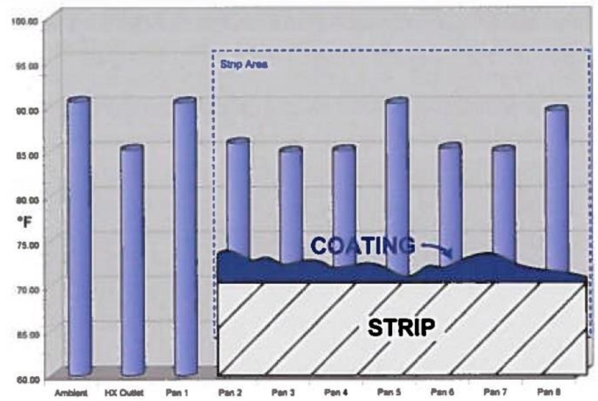


Figure 3: Relationship Between Temperature, Viscosity, and Film

Because of the relationship between temperature and viscosity, as discussed above and demonstrated in Figure 1, the warmer coating presented to the nip will be at a lower viscosity than the cooler coating. As a result, the film of coating allowed to pass through the nip will be thinner. Because of the compressible nature of the applicator roll, it is possible to have different displacements in adjacent areas across its width. This results in variation of the film across the width of the applicator roll, which is subsequently applied to the strip. Figure 3 shows how this variation in temperature across the width of the pickup roll, called the Thermal Profile, results in variation in the film build across the width of the strip.

To complicate matters further, coaters and suppliers are continuously creating higher-volume-solids coatings in an attempt to drive down the solvent content and, therefore, reduce the cost and environmental impact of VOC's in the process. These higher volume solids mean steeper viscosity vs. temperature curves, which in turn, results in even greater film variations as a result of edge-to-edge and head-to-tail temperature variations. These conflicting objectives can create a "vicious circle" of increasing processing difficulties for the coater to handle.

Correcting the Thermal Profile

In order to break this vicious circle and reduce variations in film, it is necessary to minimize thermal variations in the system. Research performed on literally hundreds of coating heads has shown that the best thermal profiles (those with the smallest edge-to-edge temperature variation) are found on heads operating in a 3-roll reverse (indirect) nip-feed coating configuration, as shown in Figure 4. In

Figure 4: 3-Roll Reverse (Indirect) Nip Feed Configuration

fact, the thermal profile measured on the head in Figure 4 is shown in Figure 5.

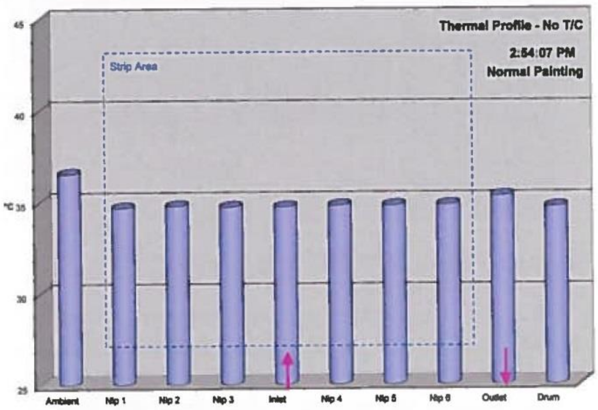


Figure 5: 3-Roll Reverse (Indirect) Coating Nip-Feed Configuration Thermal Profile

Here we can see that the edge-to-edge variation is on the order of ±0.1°C (±0.2°F). This assures that the film variations across the width of the strip as a result of coating viscosity variations are virtually non-existent. Unfortunately, the head-to-tail performance of these systems is as bad as their 2-roll reverse counterparts. The thermal performance over time of this same system is shown in Figure 6.

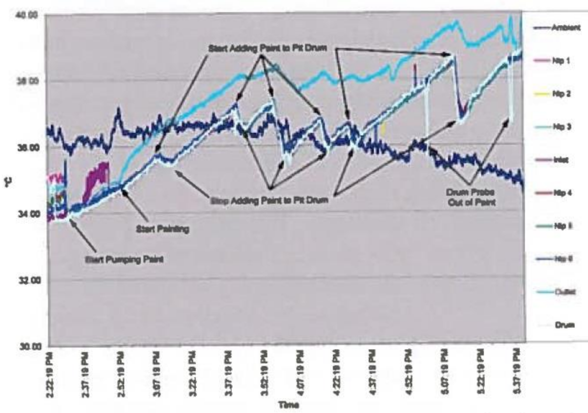


Figure 6: 3-Roll Reverse (Indirect) Coating Nip-Feed Configuration Long-Term Thermal Performance

From this graph we can see that, though the edge-to-edge profile is very tight, the temperature of the coating (and therefore the viscosity) is continually changing. The friction of the system, increased due to the use of two nips, drives the temperature of the coating up until cool coating is added from bulk supply to the pit (break) drum. This cools the coating temporarily, but between fills, the cycle repeats itself. This means that, without adjustments to parameters like nip pressure to compensate for the change in viscosity caused by the varying temperature, the film build on the strip will continually vary from the head (start) of the coil to the tail (end).

This can obviously be addressed through the implementation of temperature control. Figure 7 shows another 3-Roll Reverse (Indirect) Nip-Feed Coater both without and with temperature control. In the left-hand graph (without temperature control) we can see the same temperature variation over time demonstrated in Figure 6 above. In the right-hand graph (with temperature control), however, we can see that both the edge-to-edge and head-to-tail variations have been eliminated. In this situation, the coil will be coated evenly over its entire surface – with no adjustments required. Furthermore, this consistency will be independent of the length or width of the coil being coated and can be repeated from coil-to-coil. Best of all, this allows the same coater "recipe" to be used every time that product is run, through every season, which optimizes the setup efficiency.

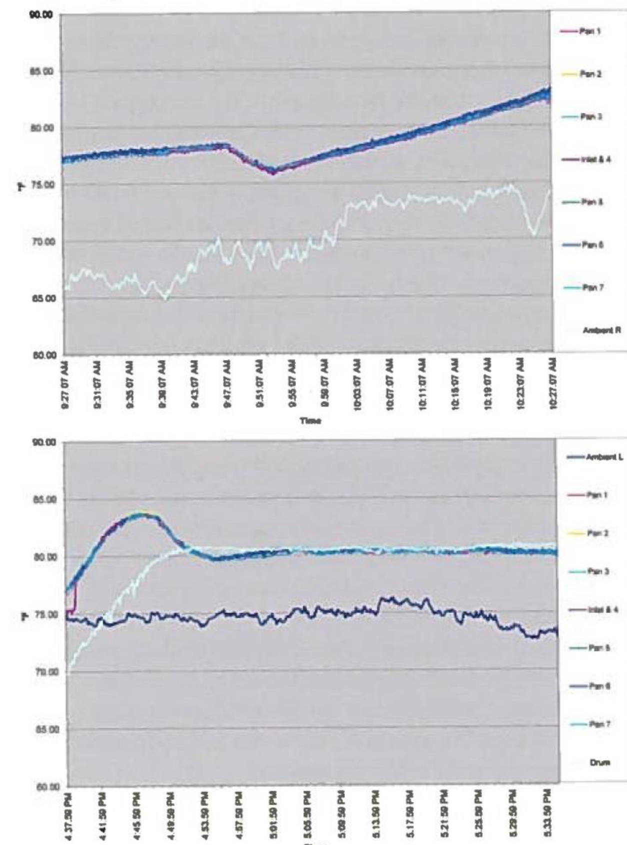


Figure 7: 3-Roll Reverse (Indirect) Coating Nip-Feed Configuration Long-Term Thermal Performance Both without Temperature Control (top) and With Temperature Control (bottom)

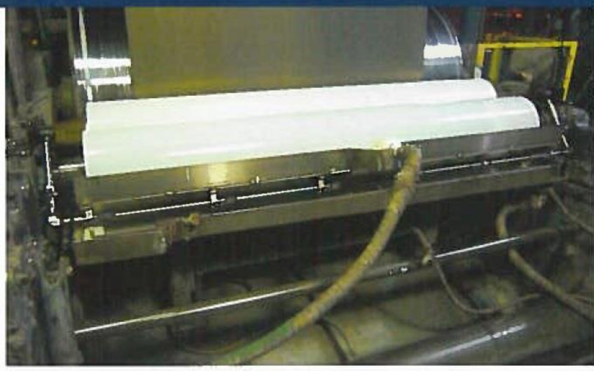


Figure 8: Profile Correction Module

So why doesn't everyone just switch to a 3-roll nip-feed configuration? In spite of its advantages, there are still many issues with 3-roll systems:

- Not all coating heads are set up for 3-roll operation
- Additional rollers are expensive
- Additional energy is required to run the third roller
- Additional maintenance is required with a 3-roll system

It's difficult to operate 3-roll configurations reliably without temperature control

The Best of Both Worlds

"[To] Promote the global competitiveness of manufacturing companies by controlling fluid temperature and viscosity at the point of use."[4]

This is Saint Clair Systems' published Mission Statment, which clearly delineates our long standing commitment to making our customers more efficient and effective. In keeping with this stated objective, we have taken these lessons learned and applied them to the development of our patent-pending Profile Correction Module (PCM). Shown in Figure 8, this innovative new device creates 3-roll nip-feed coating configuration performance on a standard 2-roll coater – with none of the complexities.

This unique, patent-pending design achieves this objective in three fundamental ways:

1) As shown in Figure 9, coating is metered to the surface of the pickup roll through a carefully controlled gap created by the physical location of the PCM in relation to the pickup roll face. This adjustable gap supports any film build, allowing it to be used with coatings as thin as Epoxies and Lacquers used for beer & beverage stock, Urethane and Epoxy Primers, common Polyester, Modified Polyester and Fluoropon based architectural coatings, and even high-viscosity, thick-film coatings like PVC's and Plastisols.

Figure 9:
PCM Metering Gap

2) This gap is continuously flushed with fresh, temperature-controlled coating from the center to the ends to drive out any material that has been in contact with the roller long enough to absorb energy and increase its temperature. This stable temperature coating in constant contact with the pickup roller helps to bring roll swell to equilibrium more quickly than in either standard 2-roll or 3-roll configurations.

3) The pan is lowered into a "catch-basin" configuration so that the coating in the pan is no longer in contact with the pickup roll and, therefore, temperature variations in the pan created by swirls and eddy currents cannot be transferred to the applicator roll by the pickup roll. Furthermore, the volume of coating in the pan no longer has any impact on the coating result, so it can be driven down to an absolute minimum. In fact, reductions in system fill-volume of up to 80% are possible.

The detailed configuration of the system is shown here in Figure 10:

The proof that this new system emulates 3-roll performance is best shown in the thermal profile graph in Figure 11, which shows less than ±0.15°F variation across the width of the "nip".

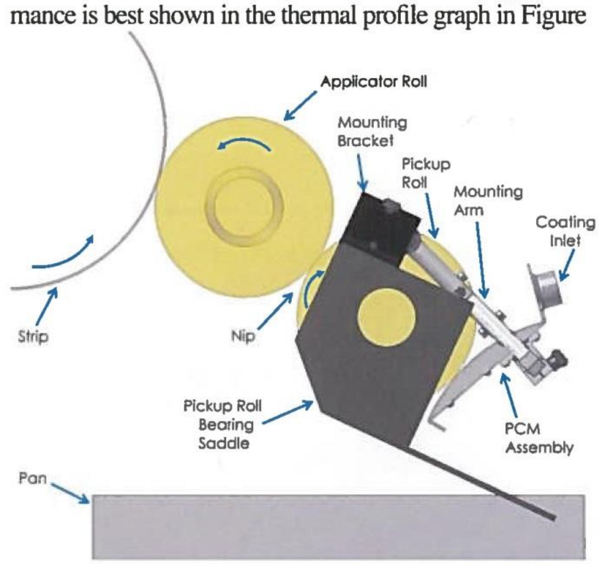


Figure 10: PCM Configuration

The advanced features of this new system include:

- Low initial cost
- Smaller fill volumes
- Quick-release mountings
- Positive repositioning stops
- Fast initial install (<2 hours)
- Negligible edge-to-edge temperature variation
- No third motor, so no added energy to operate
- Removal & reinstall < 1 minute (total) at color change
- Faster, more efficient cleanup

A Better Way of Coating

By combining the best of the 2-roll and 3-roll coating systems, the PCM system improves on the benefits of each

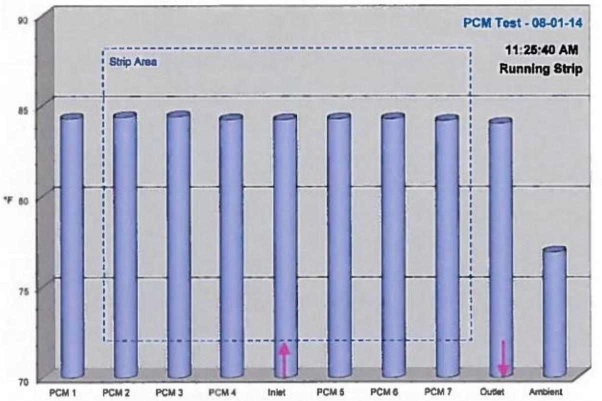


Figure 11: PCM Thermal Profile

with features that directly address the issues associated with the short-run requirements of today's coating marketplace. A quick recap is in order:

ISSUE	FIX
More frequent color changes	Smaller fill volumes speed color changes and reduce wasted paint. This controls the cost of smaller batches, especially custom color runs. The PCM's quick release mechanisms provide for fast repositioning to speed color changes.
More partial drums to handle and store	Smaller fill volumes mean less paint in the delivery system which reduces the amount of "extra paint" that must be purchased, reducing the number of partial drums. Furthermore, these smaller volumes in contact with the ambient air reduce the evaporation of solvents that make partial drums so hard to deal with.
Increased cleaning costs	Smaller fill volumes speed color changes and reduce the volume of cleaning solvent required. The PCM's positive stop, quick release mechanisms provide for fast, easy repositioning to facilitate cleaning. The limited surface area allows cleaning with a minimum of solvent.

ISSUE	FIX
Increased setups and quality checks	By creating repeatable coating recipes with the combination of the PCM and temperature control, setups are faster and quality is more predictable. The PCM's quick release mechanisms provide for fast repositioning during color change. The demonstrated reduction in edge-to-edge variation improves the quality and the predictability of the setup.
Reduced available run time	By reducing setup times, shortening color changes and making coating outcomes more predictable, available line run time can be optimized.

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2 – Bonner, Michael R. Adjusting Coating Viscosity. Coil World, May/June 2012.
3 – Paint Viscosity vs. Temperature data provided courtesy of Sherwin-Williams Corporation.
4 – Saint Clair Systems, Inc., Mission Statement.