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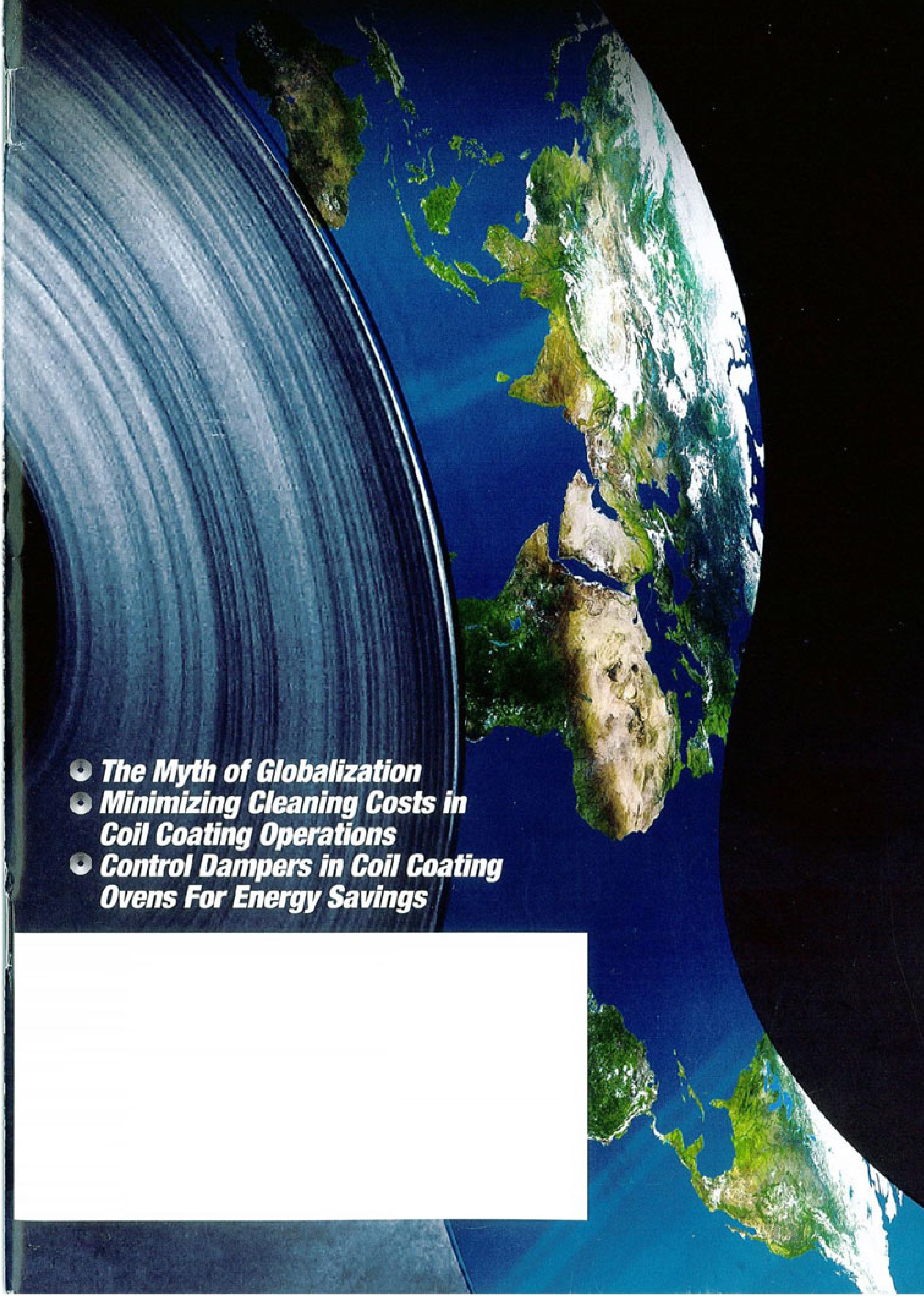


- ***The Myth of Globalization***
- ***Minimizing Cleaning Costs in Coil Coating Operations***
- ***Control Dampers in Coil Coating Ovens For Energy Savings***

CONTENTS

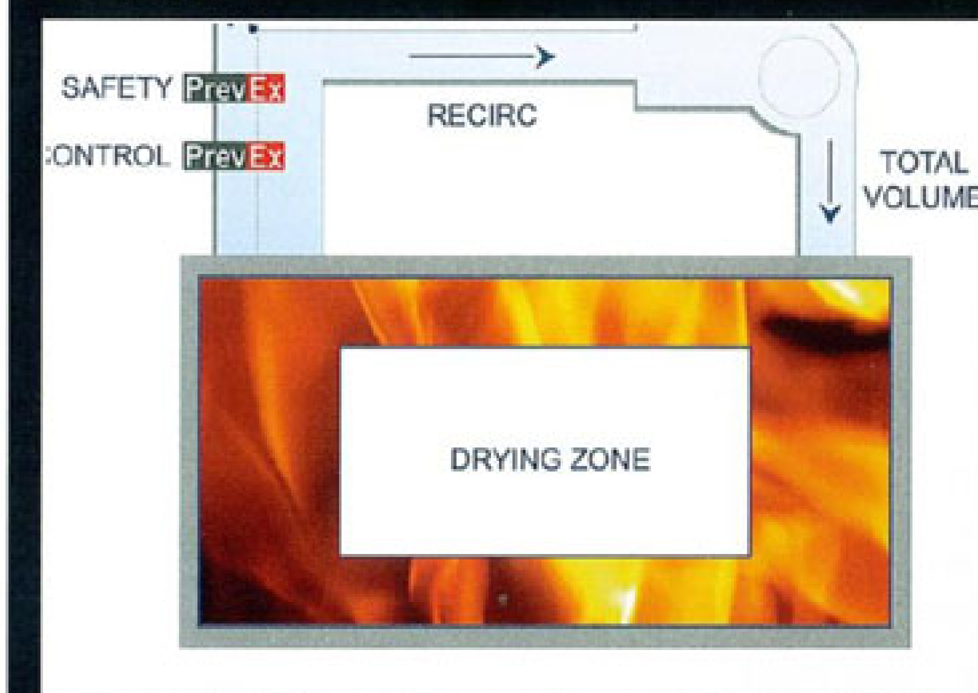
cover story

features

departments

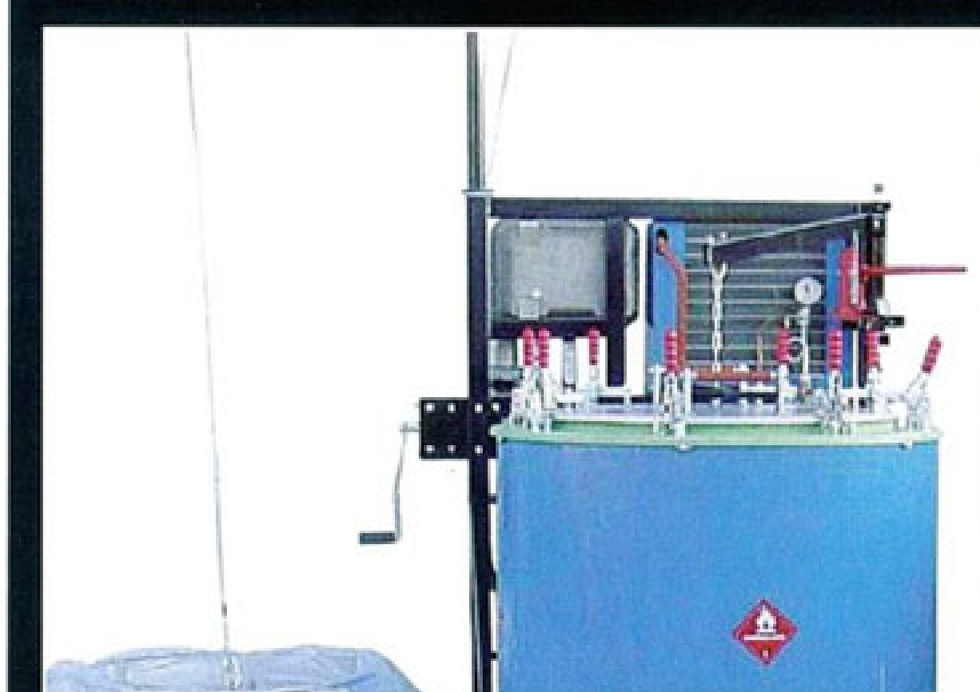
During the past 10 years almost six million jobs were lost, 4.5 million of them in manufacturing, representing the largest transfer of wealth in our history..

See page 8



Use of redundant analyzers in an oven or zone for secondary for secondary safety and cost savings is preferred.

See page 20



55-gallon Solvent Recovery System.

See page 22

Minimizing Cleaning Costs In Modern Coil Coating Operations

By Michael R. Bonner, Vice President, Engineering & Technology, Saint Clair Systems

Over the last few years, 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 – which creates the need for faster, more frequent color changes. In this paper, we will examine the pros and cons of the primary color change options currently being employed to address this demand.

The Objectives of a Color Change

The primary objectives of a color change are quite simple and include:

- Completely clean the paint path
- Reclaim as much paint as possible
- Minimize wash solvent use
- Minimize time involved

The first objective is obviously to get all of the residual paint out of the system. Here it is good to keep in mind our mothers' old adage that "Cleanliness is next to Godliness". Every painter knows that a little red contaminates a whole lot of white! Often, coaters will try to structure their schedule to minimize this impact by running white, followed by buff, then beige, then gray, then a strong color like red, blue or green, concluding with charcoal and then black. This is great if your order schedule includes this kind of color spectrum and corresponding delivery timeline to support it – but how often does that really happen? Clearly, the most flexible alternative is to have a process that allows changing from any color to any color without fear of cross-contamination.

Reclaiming as much paint as possible also seems obvious. Paint is the most expensive component in most toll coating processes – often accounting for as much as 50% of the operating budget – and so, minimizing its consumption presents the most significant cost-containment opportunity available.

Next, of course, is minimizing the amount of wash solvent used. Wash solvent is a waste product – period. Other than the cleaning function, it adds no value to the product delivered to the customer. Worse, it contributes significantly to the VOC's processed through the coating operation and represents cost and hassle with regard to both disposal and permitting.

Last, but not least, if a line is not equipped with a quick-change head configuration, a color change represents downtime – time that the line is not producing saleable product. Clearly, the shorter this time period, the better.

Especially now, these combine to make the color change process arguably the most important process that a coater employs in the quest to remain competitive.

Color Change Options

Though there are many cleaning processes in use across the market, they are all variations of the three primary color change options that we will address here:

- Paint Push-Through
- Solvent Push-Through
- Solvent Flush

The Paint Push-Through process is usually considered the fastest of the three and uses the least amount of wash solvent. The steps are as follows:

1) The pump suction tube is removed from the pit (break) drum and wiped off while the pump is still running.
2) The pump pushes the paint through with air (an option because diaphragm or piston pumps account for more than 90% of those used in all coil coating operations), and then the pump is stopped.
3) The paint is drained from the pan back to the pit drum, which is then resealed and returned to inventory.
4) The pan and rolls are cleaned with wash solvent, which dumps to waste.
5) The pump suction tube is placed in the new color drum.
6) The pump is started and pushes the paint through the system to waste until the new color comes out "clean".
7) The hose is moved to the pan to start the coating process.

In addition to the fact that there is no cleaning involved with this process, other problems include the amount of paint lost in the changeover due to the mixing of the two colors during push-through. If these are incompatible chemistries, this can create significant and lasting problems in the coating delivery system.

The Solvent Push-Through process is a "hybrid" of the other two, and is probably the most common system in use today. The steps here are as follows:
1) The pump suction tube is removed from the pit (break) drum and wiped off while the pump is still running.
2) The pump pushes the paint through with air, and then the pump is stopped.
3) The pump suction tube is placed in a solvent drum, and the pump is used to push the paint through to the pan just until solvent is observed; then the pump is stopped.
4) The paint is drained from the pan back to the pit drum, which is then resealed and returned to inventory.
5) The pan and rolls are cleaned with wash solvent, which dumps to waste.
6) The pump suction tube is again wiped off and placed in the new color drum.
7) The pump is started and pushes the solvent through the system to waste until the new color comes out "clean".
8) The hose is moved to the pan to start the coating process.

This process uses a little more solvent but results in a lower amount of paint lost in the changeover than the Paint Push-Through – but only slightly. Unfortunately, there is still significant mixing of the two colors during the push-through.

The Solvent Flush process is the most effective cleaning procedure but involves the largest number of steps and uses the most wash solvent. It is as follows:
1) The pump suction tube is removed from the pit (break) drum and wiped off while the pump is still running, and the pump pushes the paint through with air.
2) The pump suction tube is placed in a 5-gallon pail 2/3-filled with solvent, and the pump is used to push the paint through to the pan just until solvent is observed; then the pump is stopped.
3) The paint outlet hose is placed in the solvent pail and the pump restarted to circulate the solvent through the system.
4) While the solvent circulates, the paint is drained from the pan back to the pit drum, which is then resealed and returned to inventory.
5) The pan and rolls are cleaned with wash solvent, which dumps to waste.
6) The pump suction tube is removed from the solvent pail while the pump is still running, and the pump pushes the solvent through with air.
7) The pump suction tube is placed in the new color drum.
8) The pump is started and pushes the remaining solvent through the system to waste until the new color comes out "clean".
9) The hose is moved to the pan to start the coating process.

This process uses more solvent, but by utilizing recirculation, more thoroughly cleans the inner surfaces of the coating delivery system, which results in less paint lost and no mixing of the two colors during the changeover.

Table 1: Path Volume	Volume (gal)
1" x 8' Hose Drum-to-Pump	0.33
1" x 12' Hose Pump-to-Pan	0.49
1" Diaphragm Pump	0.17
Total Volume:	0.99

In order to facilitate a fair comparison of these procedures, we will look at the differences involved in implementing them on the same coater. First, we will define a 1" material supply path as shown in Table 1. Note that this system has a one-gallon capacity.

Density, Viscosity, Velocity and the Cleaning Process

So why are there differences in the cleaning efficiency of these three procedures? It all comes down to density, viscosity, and velocity.

When two fluids of vastly different densities and viscosities meet in a system, the denser, more viscous fluid displaces the lighter, less viscous fluid. This makes it hard to push a thick, heavy fluid with a thin, light one. Let's start with the example of using air to purge. When the air pushes on the paint in the delivery path, it displaces it – basically poking a hole through it – until it reaches the outlet of the supply hose. At this point, the light, thin air has established a path through the dense, thick paint – obviously, along the top of the path. Due to the difference in density and viscosity, the thicker, heavier paint will settle at the bottom, and the air will take the "path of least resistance", flowing over the paint without disturbing it. Moreover, a lot of air can flow through a small passage, so very little of the paint in the path actually gets displaced. In spite of the fact that the diaphragm pump – a positive displacement device with Teflon surfaces – will virtually purge itself, referring to Table 1 we can see that this only represents about 17% of the total volume of the delivery path. If we purge 25 – 30% of the volume with air, we have been very successful. In this example, this means that upwards of 0.75 gallons of the old paint will be wasted in the changeover.

Now let's introduce the next color. The density and viscosity of the two paints are similar, so the new paint is much more effective at displacing the old, as they will exert roughly the same force on one another. This is where the Paint Push process seems to gain some traction as a viable alternative. Of course, this is also where velocity comes into play. The new paint does not just push the old one through. In fact, they will begin to blend where the two come together. This blended coating is contaminated and is purged to waste.

Higher viscosity fluids tend to reach laminar flow much more readily than those of lower viscosity. This means that there will be higher flow along the centerline of the path than at the walls. The old paint will adhere to those wall surfaces (as a function of friction, viscosity, and surface tension) and the new paint will flow right down the center – that is until some kind of turbulence is introduced to disrupt the laminar flow. And what creates turbulence? Velocity. This is where the Paint Push process falls out again. It is necessary to pump the new paint through at maximum velocity to displace the old paint adhering to the internal surfaces of the delivery path. The faster the paint is pumped, the greater the turbulence and, therefore, the greater the "scrubbing action". Unfortunately, the faster it is pumped, the faster it goes to waste.

The same phenomena apply to the Solvent Push process. The real difference here is that the solvent will react with the paint and, by combining with it, reduce its viscosity. This takes time, however. Moreover, the extent of the viscosity reduction is limited by the ratio of solvent to paint in the delivery system, which we have already established to be somewhere in the ratio of about 40% : 60%. In the end, this approach is successful in reducing the amount of new paint required to purge the system of the old, but again, only marginally.

Enter the Solvent Flush process. This takes advantage of solvent's ability to reduce the viscosity of the old paint, and thus reduce its ability to cling to the internal surfaces of the delivery path, while leveraging the mixing and scrubbing effects of turbulence by circulating the lower viscosity solvent at high velocity. In fact, all of these parameters come together to create a "perfect storm" of cleaning.

First, if as described above, three gallons of solvent are used to purge and recirculate, and there is approximately 0.6 gallons of paint left in the system, the ratio of solvent to paint is roughly 5:1. This assures that the paint will be reduced to very near the viscosity of the solvent. Next, a diaphragm pump will pump at a flow rate that is directly proportional to the inlet pressure of the air driving it and the viscosity of the fluid it is pumping. In short, as the viscosity of the solvent/paint blend falls, the flow rate increases and with it the mixing and scrubbing action associated with the increase in turbulence. With the internal surfaces of the delivery path now coated with a very light, thin blend of old paint and solvent, the new color has no trouble displacing it with very little waste.

The Myths of Time and Cost Savings

For the rest of this analysis, in addition to the one-gallon delivery system we defined above, we will also make a few procedural assumptions here:

- A known color with a defined recipe is being used
- No trials are required for the setup
- All required tools are staged prior to color change
- The wash solvent is staged prior to color change
- The new paint is staged prior to color change
- one gallon of wash solvent is required to clean the rollers and pan

If the same color change is performed with each of these procedures, we can perform an industrial engineering study to determine the time associated with each step and thereby arrive at a total time for each procedure. This is shown here in Table 2:

Clearly, these times will vary from line-to-line and even operator-to-operator. We have seen well-tuned

Operation	Time (minutes)		
	Paint Push	Solvent Push	Solvent Flush
Remove pump suction tube from pit drum and wipe off	0.25	0.25	0.25
Push the paint through with air	0.25	0.25	0.25
Stop the pump	0.08	0.08	0.08
Place pump suction tube in solvent drum/pail	N/A	0.08	0.17
Push paint through to the pan until solvent is observed	N/A	0.50	0.50
Stop the pump	N/A	0.08	0.08
Place paint outlet hose in solvent pail and circulate solvent through the system	N/A	N/A	0.17
Drain paint from pan back to the pit drum	1.50	1.50	1.50
Reseal drum for return to inventory	0.33	0.33	0.33
Clean pan and rolls with wash solvent	2.00	2.00	2.00
Remove pump suction tube from solvent pail	N/A	0.17	0.17
Push the solvent through with air	N/A	0.25	0.25
Place pump suction tube in new color drum	0.08	0.08	0.08
Start pump and push through system to waste until new color comes out "clean"	2.00	1.50	0.50
Stop the pump	0.08	0.08	0.08
Move hose to pan to start coating process	0.08	0.08	0.08
Total Time (minutes):	**6.65**	**7.23**	**6.49**

Table 2: Industial Engineering Study showing steps and timing for each procedure.

operations trim these times to less than five minutes, but this gives a good overview of the steps and timing involved and shows that there is very little time difference between the three procedures. In fact, the most commonly used procedure is actually the slowest, and the best procedure for cleaning is also the fastest, primarily because it is not necessary to push the old paint through with the new color – a time consuming and expensive operation.

So, now that we have debunked the myth that a Paint Push process is the fastest changeover procedure possible, we can turn our attention to the subject of cost…

At first glance, it seems intuitively obvious that the Paint Push process reduces both the number of steps in the procedure and the volume of solvent used and so will produce the most cost-effective cleaning process. This theory can be confirmed by stacking up the costs like we did the timings. This is shown in Table 3.

	Paint Push	Solvent Push	Solvent Flush
Paint Cost/Gallon:	$ 40.00	$ 40.00	$ 40.00
Solvent Cost/Gallon:	$ 6.00	$ 6.00	$ 6.00
Gallons Paint Lost:	4.0	3.0	1.0
Gallons Solvent Used:	1.0	2.0	5.0
Cost of Paint/Change:	$ 160.00	$ 120.00	$ 40.00
Cost of Solvent/Change:	$ 6.00	$ 12.00	$ 30.00
Total Cost/Change:	$ 166.00	$ 132.00	$ 70.00
No. Changes/Day:	16	16	16
Cost of Changes/Day:	$ 2,656.00	$ 2,112.00	$ 1,120.00
Operating Days/Year:	300	300	300
Annual Cost of Changes:	$ 796,800.00	$ 633,600.00	$ 336,000.00

Table 3: Associated paint and solvent costs for each procedure.

The top half of the table is highlighted in yellow to show our assumptions. These are all quite conservative but still clearly illustrate the difference in cost of each procedure. Once again, the intuitively obvious assumption regarding the cost of the Paint Push process proves false! In fact, the best process for cleaning is not only also the fastest, it is also the least expensive – less than half the cost of the Paint Push process.

These costs were calculated based on just 16 color changes/day and operating just 300 days/year. In reality, many coaters are already running well in excess of those numbers! Clearly, there is a great deal of money on the table, so optimization is essential.

Taking It to the Next Level

Obviously, the first step is to implement a well-defined solvent recirculation color change process that reclaims as much paint as possible. Once that is in place, the next objective has to be to reduce the volume of wash solvent used in the process – without losing the benefits. While it may be possible to reduce the volume of wash solvent used to clean the rolls and the pan from the gallon allotted, this will still be just a fraction of a gallon per color change. In the recirculation process, the 5:1 solvent-to-paint ratio places the lower limit at about three gallons, so again, only a fraction of a gallon per color change is available there. Fortunately, there are other options available.

It turns out that after the cleaning process is completed, the solvent is still viable; it is just saturated with paint. If the paint solids can be removed from the solvent, the solvent can be reused. The solution then, is to reclaim the solvent. The first option is to decant the used solvent, allowing the solids to settle and then pumping the liquid off the top. This is a slow process and requires significant volumes of used solvent to be stored. In addition, the remaining byproduct is still a hazardous waste that must be stored, handled, and ultimately disposed of. This is clearly not in line with the inventory and permitting reduction objectives discussed at the beginning of this article!

A better solution is distillation. In this process, the solvents are boiled off and collected, leaving only the solids to be disposed of. If all of the solvent can be removed, what is left is a dry cake, which is basically inert plastic, and can be disposed of in the solid waste stream. This is significantly less expensive than disposing of hazardous waste! Furthermore, if the solvent is reclaimed and reused, less wash solvent is purchased, which not only reduces cost but also reduces permitting requirements. There are several commercially available systems on the market, the best of which offer a UL-approved distillation system that is low cost, intrinsically safe, and capable of reclaiming more than 95% of the solvent in each batch. An example of such a system is shown in Figure 1. This particular system distills the solvent, leaving the dry powder cake in an easy-to-dispose-of poly-bag. There is even a hoist to assist with lifting.

Figure 1: 55-Gallon Solvent Recovery System
(Photo Courtesy of BECCA)

Table 4 shows that if one of these systems were implemented on the Solvent Flush example above and a reclaim rate of just 80% were achieved, it would result in an annual savings of more than 19,000 gallons of solvent, which represents more than 70 tons of VOC's, and a cost savings of more than $115,000. In short, this

	Solvent Flush	
Annual Solvent Use (Gal):		24,000
Annual Solvent Cost:	$	144,000.00
Solvent Reclaim Rate:		80%
Annual Solvent Savings (Gal):		19,200
Annual Solvent Cost Savings:	$	115,200.00

Table 4: Solvent reclaim cost savings.

would again cut the cost of color changes in half.

Competitiveness through Targeted Cost Savings

Each year, every operating coil coating facility spends hundreds of thousands of dollars changing between colors. This investigation has shown that this can be reduced by as much as 75% by:

1. Implementing a carefully designed and consistently executed color change process that utilizes recirculating solvent cleaning to minimize the paint consumed in the changeover; and,
2. Implementing a distillation process to reclaim used wash solvents, while significantly reducing VOC use and improving a coater's permitting position and environmental footprint.

In this tough, competitive environment, no coater can afford the luxury of ignoring the cost reductions achievable in the color change process.