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GLOBAL SMT & PACKAGING

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Nanocoating Can Increase First Pass Yi

What Does Industry 4.0 Actually Deli Today?

2018 Milestone Anniversaries

Software and Data Security in 2018

APEX EXPO IPC 2018

SHOW PREVIEW

INTERVIEW INSIDE

Robert Saller, CEO at DELO

CASE STUDY

Nanocoatings Can Increase First Pass Yields

How Rauland Reduced SMT related defects by over 50%; Increased throughput by over 20% and saved $1 million in three months

Rauland is an 80-year integrated communications technology company that builds nurses call stations and school bell systems. Experiencing a large number of defects and disruptions in the SMT line, Rauland SMTA certified process engineer Jimmy Crow, who runs a factory that builds four- to eight-layer PCBs, replace BGA, CBGA, QFNs, typical double-sided boards, with their smallest part to date an 042-Aperio, sought to mitigate them. His goal was to increase throughput while maintaining ideal quality.

Jimmy Crow was interviewed about his processes and results by Chrys Shea, an SMT industry veteran and owner of Shea Engineering Services. The interview follows the process Jimmy Crow took to increase first pass yields and decrease SMT defects.

The Interview

CHRYS: I've been working with nano coating and stencil coatings for a very long time. It was this time last year during APEX when I met Jimmy Crow. We're both engineers that think in a similar manner. As we talked, he told of all the great results he's had with the stencil printing improvement process. Please allow me to introduce Jimmy Crow. Jimmy, take a moment to tell everyone about yourself and the products you build.

JIM: Good morning, everyone. I'm a senior project engineer at Rauland. I spent 10 years in naval intelligence before starting my SMT career as a machine technician. Eventually, I became a SMT process technician before becoming an SMTA certified process engineer. Now my focus is on SMT processes and process improvement methodologies. I work for Rauland, a company that has been setting the standard for integrated communications technology for more than 80 years. We build nurses call stations and school bell systems. To that end, we build four to eight layer PCBs, we place BGA, PCBGA, QFNs, typical double-sided boards, with the smallest part to date an 042-Aperio. We're moving to 0201s. Our manufacturing facility has two shifts.

CHRYS: Why did you pick the stencil printing process to cut your costs of SMT over the others, and how did you go about identifying the best practices and where to attack it?

JIM: We had a large number of defects being captured in our AOI end of SMT line process, so I opted to begin the improvement process with the low hanging fruit. Studies have shown 65% of defects from SMT lines comes from the screen printing process, and this was certainly the case in my factory. I started concentrating on the screen printing process which has the largest impact over yield, throughput, quality, and downtime costs. I concentrated primarily on process improvements which, in turn, increased our process capabilities.

CHRYS: Tell us how you decided to attack stencil printing.

JIM: Well, initially I started with what I thought was the most obvious thing. I started with the things that actually clean the screen mechanically. The paper and the under-screen solvent. And I got a lot of information on different types of paper. I ended up with a paper I thought was more porous, to allow for better wiping. And then I investigated several under-screen solvents. I chose Zestron Vigon UC160 in the end and as I started to play with them, I noticed improvements, but it still didn't give me the ability to clean my new SMT line, which had a 22 second mean cycle time. The gate or the screen printer was always stopped to clean every 2 ½ minutes. The SMT line would empty of boards so I looked for throughput. My goal was to increase throughput while maintaining great quality. And that is where the nano coating really made a difference. It allowed me to start running much more efficiently without having to stop every three to five boards to clean.

CHRYS: Yes, we all learned early on when we learn about line balancing that your stencil printer should never ever, ever be the gate on your assembly line. The most expensive piece of equipment, which is usually your placer, should be your gate. If you have a $2 million piece of equipment waiting for a $100k piece of equipment to feed it, you're not making a lot of money.

JIM: Exactly. That was the case.

CHRYS: Let's talk about the first few changes you made. The IPA to engineered solvent, Vigon, and then to paper. What's the purpose of the under-wipe solvents?

JIM: Regarding Vigon, I wanted to find something that wasn't harmful to my screen printer, yet was able to work efficiently. I also bought a water-based system that removed solder. I wanted to clean the stencil in a way that cut down on the amount of time, rather than wiping the stencil three times to get it clean as was done previously. I cleaned it right away with the new solution, a product that is easily handled and can address our markets abroad.

CHRYS: Well, the water-based solution evaporates a little more slowly than the IPA, but do you make that up in cycle time because you don't have to wipe as often?

JIM: Yes, it's true that water-based solutions evaporate a little more slowly, but we make it up in cycle time because we

are able to run so fast. We're able to clean less often. We no longer have to clean every fourth or fifth board.

CHRYS: Fantastic. Now why was IPA problematic for you?

JIM: We found the IPA problematic. It was very hard to maintain solder viscosity and maintain the machinery with IPA. And we found out it did not clean as efficiently as we wanted it to and we ended up using more of the paper, more of the roll just to get it clean and we had to clean more often. When the brick falls through the aperture walls, the IPA did not assist in getting it clean. Sometimes when you do a stencil clean, as most folks out there would know, it may take two boards just to get the print, the brick to fall through onto the pads of the board correctly. We found we had more problems with the IPA. And then at one point I turned off the IPA and sprayed nothing, and I had about the same results as I did with IPA.

CHRYS: Well, you know we found similar results repeatedly in the labs back in the tin lead days. IPA was a great solvent because it dissolves all the naturally occurring rosins in the solder paste. Now that our newer solder pastes are comprised of synthetic resins, alcohol just does not cut it anymore. In fact, it makes it worse. We've seen that some solder paste can gob them up and clog the aperture as opposed to clearing them. Now what about switching your wipe, aka textile.

JIM: I learned a lot from the folks at MicroCare about wipes. Today's wipes are more porous, with more openings, which are designed to absorb better, designed to get the necessary wipe in one wipe. If you combine a better solvent, a better paper, and a then you have a substance which helps repel solder, it makes a magic mixture for reducing solder residue or solder buildup. And a good screen printing program always helps. If you can design a better screen printing program, setting up things like your snap-off and your print and your speed, together, showed amazing results for me.

CHRYS: You're absolutely right. You must take that systemic view overall. What I think we've done in printing over the years is we optimized the overall system and now, to get those little advancements, to get to those 0201s and those 0105s, we're going in and optimizing our subsystems. We're finding our better paper, finding better solvent, finding a better paste. When we use the more porous paper, we like that open structure, it captures those solder balls better than some of the closed structure fill papers. When we combine the good wiper textile, the appropriate solvent, and the NanoClear, I like to call it the "triple play." And you know how rare triple plays are.

JIM: They're very rare! This is the trifecta!

CHRYS: And the new softer wipe has helped you because you're getting better printing?

JIM: Yes. It's helped us get better printing. Everything relates in dollars. Whether its loss of revenue, loss of time…it's all dollars in the end. So, we spent a quarter to save a dollar in the wipes. It has a tangible, measurable response. I'm in an FDA compliant environment, so everything must be validated with a clear process. This has had a measurable effect upon us.

CHRYS: I think your best take-away here is this reduced roll usage and downtime for changeovers. It seems in the 25 years I've been doing SMT there's been a never-ending battle between process engineers that want good high quality, more costly wiper paper and supply chain purchasing agents that want to save the most money. You're always running and one day you get this really lousy paper and you have to say "no, this is not a commodity, buy the best paper". I think you just made a really good case study for people investing in good paper.

JIM: I agree wholeheartedly. Moving from cleaning every fourth or fifth board to cleaning every 24th board answered that question. And I respect the bean counters, but they did put us to task to justify the cost.

CHRYS: They do. And a lot of times you need to do a few extra wipes because your paper isn't as absorbent so you're losing it right there. I have some pictures you provided us of the different between the new softer wipe dry and what we've known for years is some of the best paper in the business - Sontara with the IPA.

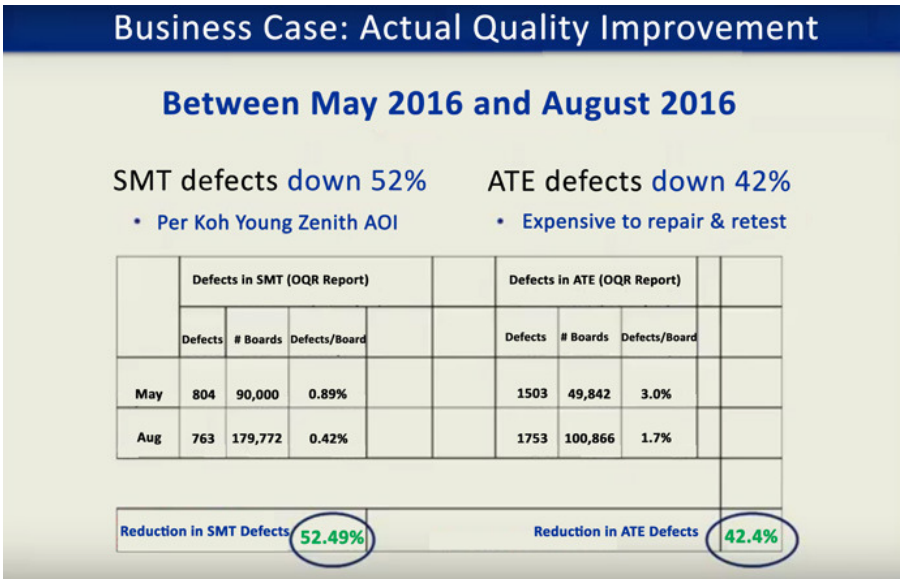
JIM: Those images are from when we were doing our studies.

CHRYS: That's amazing. You can see how the IPA can actually help that solder paste congeal and cling onto the apertures versus releasing. And now we're getting to your magic bullet. The NanoClear.

JIM: NanoClear was the missing piece of the puzzle. We made all the changes we were aware of and still had issues. Then I learned about NanoClear at one of the IPC conferences. A friend of mine told me, "Jimmy, these things you are trying to do; there are people out there already doing them." That's when I was introduced Chrys Shea. I watched some of your videos and found out you guys were already doing the very thing I was trying to do in a production environment. Your scientific expertise validated my issues, as well as the answer I was looking for. When I added NanoClear, I was able to double my screen printing variation. Instead of cleaning every fourth or fifth board, I hoped to clean every eighth or ninth or tenth board while maintaining quality.

CHRYS: And we generally say that you can double your wipe frequency when you nanocoat. That's pretty much a rule of thumb. You were going after the rule of thumb. And that is your business case.

JIM: Right. We were wiping every four to five boards based on the severity of the stencil. It was a formula stencil with maybe BGAs and PBGAs, was maybe every four. It varied between every four and six. Five was the average. And then we comfortably got to 25 cycles on several products. Not every product but several products. You have to remember this was a production environment – theses boards were going to go out the door. So in this production environment, we had to validate the products and process. We were able to prove that we could run with 25 cycles and our AOI machine and our ATE testing saw no reduction in quality. It was a measured event and we saved a lot of time.



CHRYS: That's amazing and you also bring up a good point regarding production. You can't test it until it breaks like I can in a lab. You have to keep nudging because you can't build broken boards.

JIM: Exactly. They all have to work.

CHRYS: So now we've got your calculations for the throughput improvements you were hoping to get.

JIM: Yes. We had very conservative numbers we were hoping for. While reducing defects was certainly part of it, I figured that if we get a better process, we would reduce defects. My goal was to keep up with my very fast SMT line we had just purchased, and I had hoped to get just a few seconds, so the screen printer wouldn't be the gate. The results turned out to be pretty amazing. We blew away all our projections.

CHRYS: That's amazing! 35% throughput improvement over the course of a year. That's got to add up to big, big, big, big dollars.

JIM: I had several projects including Big Brother software to make us a smart factory and a brand new SMT line. Our projections were conservative. We had a faster screen printer, a faster SMT line and this process allowed us to maintain our integrity; we were able to maintain and improve our quality while running faster. If you can run with better quality and higher throughput, that is the magic that everybody is looking for.

CHRYS: We always have jokes as new product engineers: do you want it fast, cheap or good. Pick two out of three. Is it really possible when you're making it faster and less expensively to make it better?

JIM: It was possible in this scenario. The facilitator was the brand new SMT line. So we were able to make things faster because of the products we build. As you know the first process in the SMT line is the screen printing. Like I said before, everybody agrees that about 65% of your defects originates at that point. To me this was low hanging fruit. My approach was to attack each component of the process, eliminating the defects at their origination point.
In determining the issue and finding the solution, I was able to identify NanoClear as the magic bullet for increasing our throughput. We've increased throughput and are building better boards with less defects.

CHRYS: So you got your throughput up by a third and, in the meantime, your Koh Young Zenith is telling you have 52 percent less defects.

JIM: Yes. Because we were able to now measure because we have Koh Young SPI and AOI, we were able to take measurements and compare how we ran before and how we ran after. We were wiping every fourth or fifth board. In wiping that often, typically the next board is not great. It takes the second or third board before you really get running again. By the fifth board, we were wiping again. When we were able to wipe a board and the have the next board come out perfect, we were thrilled to have that perfection spread to the fifth, tenth, fifteenth, and twentieth board – and our SPI showed no defects. We were quite amazed. It took some convincing because these numbers were unheard of.

CHRYS: You know sometimes I run tests and If I weren't the one collecting the data, I wouldn't believe the results. I think that's the case for you, as well. Right?

JIM: Yes. I'm a process engineer, not a scientist like yourself, so it was even tougher for me to believe.

CHRYS: So this means the less defects at AOI, you are probably also getting less false calls at AOI, and your operators are picking up soldering irons and taking them to boards only half as many times as they were before.

JIM: Yes. It is an amazing thing not to have defects. A solder joint made in a reflow oven is infinitely better than one done by hand, and when we repair something there's always possibility of destroying pads on the boards or not using the right solder (we still use both lead and lead-free). We just want to build it right the first time.

CHRYS: Oh yeah. I did MRB for a couple years and some of the nightmares that come out of rework from bad rework kill you.

JIM: We have suffered in the past because of reworks. We've had migration issues and all kind of things. Nothing is better than building it right the first time.

CHRYS: Oh yeah. No mixing fluxes, no scorching boards, no delam, no mix metals. Yeah.

JIM: It is an infinite number of things that you have to adjust if you're going to repair

boards and inspect your way into quality.

CHRYS: That's absolutely right. You've said a couple times in previous conversations you cannot inspect quality in. You have to build it in.

JIM: You cannot. Making better processes is worth the time and money saved. And you get a higher degree of confidence when you send those boards on to ATE or a functional test or someplace else.

CHRYS: And now looking at ATE, that's the really expensive defect to find. We have the rule of tens where, you know, if you find a bad print at SPI or the printer costs you a dollar to clean it. If you find it after reflow and you have to take an iron to it, it'll cost you ten dollars to clean it. If you find it at ATE, it cost you one hundred dollars because you have to run the test twice and if you find it in the field, it'll cost you a thousand. Now, when I started over 25 years ago, we used to say fifty cents, five dollars, fifty dollars and five hundred, so I've adjusted that rule for the time value of money. But the point is ATE defects are expensive because the test stands are expensive, the fixtures are expensive, the overhead rates are expensive. If your tech has to test it twice and he's the one taking an iron to it, that's a little dangerous as well. So, getting those down is probably a larger cost savings than getting the SMT defects down.

JIM: Right. We have an ATE with a great bunch of folks down there. We have a BGA repair machine. We have lots of special machines to do repairs. Our goal is to put them out of business. They do a great job, but we really want them to not have to do those repairs anymore

CHRYS: That's an excellent goal. Put the rework people out of business. I like that goal. Now that brings us to the cost savings for the payback calculator that I created for Aculon a couple years ago. It can be downloaded online from aculon.com- and it's very easy to use. Everything is transparent. There's nothing hidden; there's no locked cells, so there's no hidden calculations. It's currency neutral and it gives you a couple different options. So, why don't we walk through the business case that Rauland has used?

Operating Cost Savings Estimated

Cost of Simple Rework	
Time Required (min)	4
Labor rate, per hour	23
Benefit rate (%)	25
Overhead rate (%)	25
Cost of Simple Rework	$ 2.30

Cost of Wiper Paper	
Cost per roll	20
Length of roll (m)	10
Advance per wiper pass (mm)	5
# of wiper passes in cycle	3
Cost of Paper per Wipe Cycle	$ 0.03

Cost of Complex Rework	
Time Required (min)	60
Labor rate, per hour	23
Benefit rate (%)	25
Overhead rate (%)	25
Cost of Complex Rework	$ 34.50

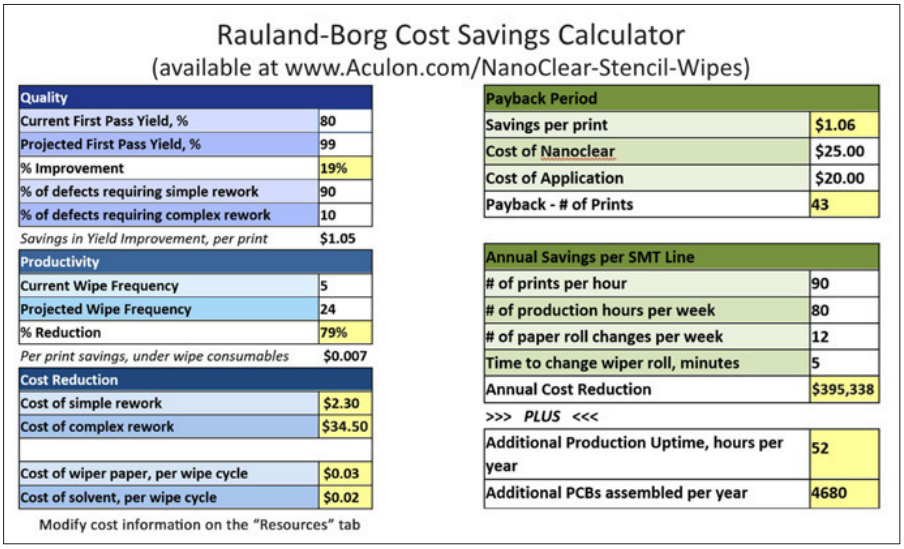
Cost of Wiper Solvent	
Cost of solvent container	30
Capacity of solvent container (L)	4
Volume of solvent used on each wipe (ml)	2
# of solvent passes in wipe cycle	1
Cost of Solvent per Wipe Cycle	$ 0.02

Now, Jimmy, your interns put the case together for you?

JIM: Yes, my interns presented this information in their final. According to their calculations, we saved a million dollars in three months. I checked and rechecked their numbers and found this to be accurate.

CHRYS: In calculating savings, simple rework is something that uses hand tools and iron, wick, solder, sucker – and complex is something that uses a special machine like a VGA or QFN. In calculating the time required for simple rework, for fixing and logging the defect is about four minutes. Figure local labor rate, benefit and overhead rates to 25 percent. And the US and Europe and probably 15 to 20 depending on your location. These add up to cost about two dollars, two and a half dollars to take an iron to the board. Complex rework takes about an hour if you're really getting into the intricate details causing it to be a lot more expensive. So that's about thirty-five dollars. Consider the cost of wiper paper, the length of the roll, how many advances used on a wipe, and the average advance per wipe. And when you look at your solvent, figure the cost of the container, how many liters are in the container. The typical dispense rate measured off a deck machine is about two milliliters, and usually do one solvent path. So every time you wipe, you've got about three cents a paper and two cents of solvent, so it's about five cents in consumables per wipe - which also takes a lot of cost out if you go from five to twenty-five.

JIM: The quality was averaged across all four lines. They determined initial quality was 80% first-pass yields across all 4. The goal was 99%. We found that simple defects requiring rework represented 90% of total defects. And only 10% were the harder things to repair. The current wipe frequency was about five, as an average. We projected wipe frequency was twenty-four. You can see the reduction at 79%. That is the big number that helps us justify the cost. If you can safely and repeatedly double the number from five to ten, most times you see a huge savings. Our cost reduction and the simple rework, the cost of complex rework and the cost of wipes, those are numbers that Chrys went over. And the payback period, the savings per print, the cash cost of the NanoClear out a week is not out as twenty bucks. Cost of application is twenty and the payback is forty-three. Now those numbers are very conservative. The cost of application, once we got really good at it, became almost half of that because we were able to do it in much less time. There is a video on aculon.com that demonstrates how to do it. The number of prints per hour: ninety. Production hours per week are eighty hours. And the number of paper rolls per week was around 17, but it's not quite that many anymore. Time to change the roll: five minutes.



Rauland-Borg Cost Savings Calculator
(available at www.Aculon.com/NanoClear-Stencil-Wipes)

Quality	
Current First Pass Yield, %	80
Projected First Pass Yield, %	99
% Improvement	19%
% of defects requiring simple rework	90
% of defects requiring complex rework	10
Savings in Yield Improvement, per print	$1.05
Productivity	
Current Wipe Frequency	5
Projected Wipe Frequency	24
% Reduction	79%
Per print savings, under wipe consumables	$0.007
Cost Reduction	
Cost of simple rework	$2.30
Cost of complex rework	$34.50
Cost of wiper paper, per wipe cycle	$0.03
Cost of solvent, per wipe cycle	$0.02

Modify cost information on the "Resources" tab

Payback Period	
Savings per print	$1.06
Cost of Nanoclear	$25.00
Cost of Application	$20.00
Payback - # of Prints	43

Annual Savings per SMT Line	
# of prints per hour	90
# of production hours per week	80
# of paper roll changes per week	12
Time to change wiper roll, minutes	5
Annual Cost Reduction	$395,338
>>> *PLUS* <<<	
Additional Production Uptime, hours per year	52
Additional PCBs assembled per year	4680

What you see is an annual savings. Not the six months savings. Then the annual savings across two shifts is quite considerable.

CHRYS: Excellent. Also, because you're not changing wiper rolls so often, you're getting an extra fifty-two hours over a shift week of extra production in a year.

JIM: Yes.

CHRYS: And according to the numbers you put in that equals about 4500 or 4600 boards.

JIM: Yes.

CHRYS: When it comes to the bean counters and they don't want to pay for better wipe or paper or forty-dollar essential applications, we ask them "okay, if you could make an extra five thousand boards a year, what's the average sales price per board?"

JIM: Yes.

CHRYS: The cost of the "triple play" pales in comparison of the benefit, no doubt. Usually regardless of the improvement we will see a payback and less than two hundred prints. You said you had about two hundred stencils so at a cost of twenty-five dollars an application, you're looking at a total investment across all your stencils is about five thousand dollars to save three hundred ninety-five thousand dollars.

JIM: Yes. We nano coated all of our stencils. That lead to a barcoded stencil database we created, which indicated which stencils were nano coated. We also have the NanoClear test pen where ever quarter we audit every stencil in the building. We check to make sure NanoClear is still working to maintain the quality of the stencil.

CHRYS: That is a fabulous stencil maintenance program. It's a best practice. People need to pay attention to that because, so many defects are made in stencil printing and so many broken, dirty or busted stencils and put back in the racks. That is best practice; managing your stencils is critically important, so I think you took that triple play and you turned around and hit one out of the park.

JIM: It was such a win that our management wanted to make sure we did not lose the effectiveness of the NanoClear, which was the catalyst for the database. This quarterly process ensures the NanoClear remains active. We also use Zestron both in our under-screen printer solvent and our stencil cleaning machine, which is compatible with NanoClear wipes. We built a lot of processes around maintaining the NanoClear coating.

CHRYS: That's good, because as most of us know, it doesn't matter what nano coating you're using - they do wear over time as a result of the abrasion of the paper, so to make sure it's active is very important and it's also important to know that with the NanoClear wipe on, if it starts coming off, you can put it back on again just pull the stencil off the rack, clean it really well and apply the NanoClear. You don't need to buy a new stencil to get a nano coating on it. I think the flexibility of NanoClear in that respect is a real winner for nano coating users.

JIM: Yes. We were able to apply NanoClear to over 230 stencils. I did the first few myself, then taught another engineer the process. It is not a complex system. It's very easy to apply and has a simplistic test method to make sure it's applied correctly.

CHRYS: I carry packets with me so when I run into somebody's stencil printing problems, I'm like, "hey, let's try this. What do you do know?" The problems go away.

CHRYS: So to finish I'd like to mention how to get the best usage out of your NanoClear. Make sure you have a nice clean stencil before you apply it. And even if your stencil is brand new, fresh out of the box, you need to clean it because even new stencils have picked up debris; cleaning solvents, oils, etc. So make sure they are clean. We've also found the softer wipes like the MicroCare wipes that Jimmy is using, from internal testing, we've determine these are better wipes to use to help preserve the structure of the Nanoclear. Use a good underwipe solvent like Jimmy switch from IPA to Zestron. A couple issues with IPA that we mentioned: it can change the viscosity and make the paste clog the apertures. We've had situations where apertures were being clogged, so we applied the nanocoating which didn't fix the problem. It was because they were still using IPA as the solvent. That's another good reason to get away from IPA and move to these engineered solvents that are specifically for your solder paste. Wipe less frequently. Obviously, with the coating, you don't have to wipe as frequently. The less abrasion you put on the nanocoating, the longer it will last. And as Jimmy said, periodically check the coating with a dyne pen to make sure if is still effectively. If it's starting to wear away, open up a new packet and apply another one.