"Advantages of Multilayer Slide Coating" prepared by:

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Advantages of Multilayer Slide Coating

This paper presents a discussion of a multilayer slide coating application at Polaroid Corporation. Due to economic conditions, a coating plant located in Building W5 in Waltham, MA, was being closed. This plant coated both the Receiver Layer structure, shown in Figure 1, and the Aqueous L layer, shown at the bottom of the structure in Figure 2. Both coatings needed to move to Polaroid's New Bedford multi-station coater in NB6. This coater was built to produce the Helios system of products, a carbon based imaging system with five layers on one base and a sixth layer on a second base and a lamination step to bring the two webs together.

To fit the new coatings into the NB6 production schedule, both products needed to be run simultaneously. The original layout of NB6 is shown in Figure 3, which was modified with the addition of a second wind-up. The layout for these two new products with the new wind-up is shown in Figure 4. With 3 stations, and 4 coatings, the receiver D, U, and O layers needed to continue to be coated as a multilayer slide coating at one station. The Receiver structure is shown in more detail in Figure 5.

Since the early 70's, Polaroid has used slide coating to coat the photographic structure shown in Figure 2 above the Aqueous L layer, in this case 16 layers. But the NB6 operation had not seen multilayer slide coating in any products. This paper discusses two of the operational issues encountered when multilayer slide coating was started in NB6, and the steps taken to correct them. In addition, some guidelines have been developed from the slide coating literature to maintain a high quality level while using this coating method. These guidelines are discussed here for learning purposes. This paper is complementary to a presentation, "Advantages of a Multilayer Slide Coating – a Retrospective on a Successful Transition", made at the 2009 AIMCAL Fall Technical Conference in Amelia Island, FL, on October 18-21, 2009.

A picture of an EDI 5-layer slide coater is shown in Figure 6. Each layer enters the slide through a slot opening in the face of the slide. The top layer of the package comes out first at the top of the slide, and the bottom layer of the package comes out of the last slot of the slide. The entire package leaves the slide at the bottom edge, in close proximity to the web, which is traveling over the

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Polaroid Film Product Structure

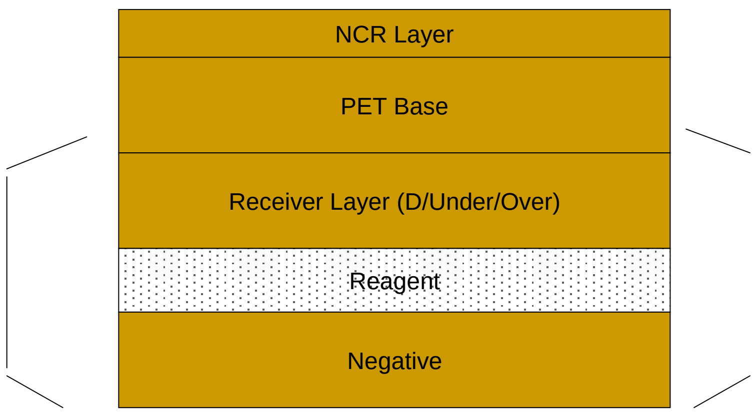

Figure 1

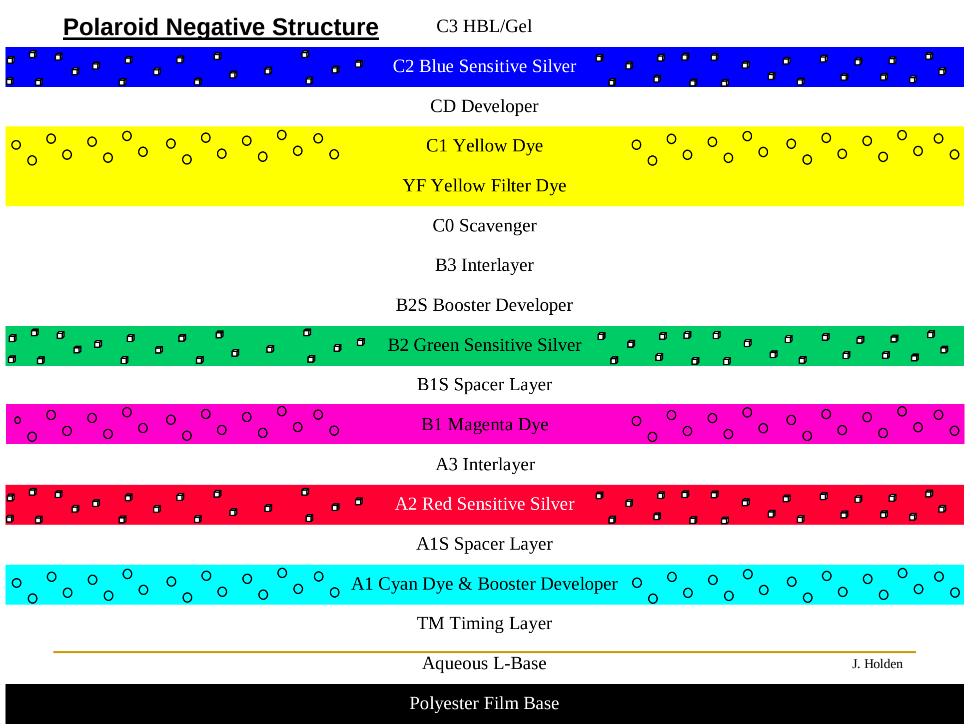

Figure 2

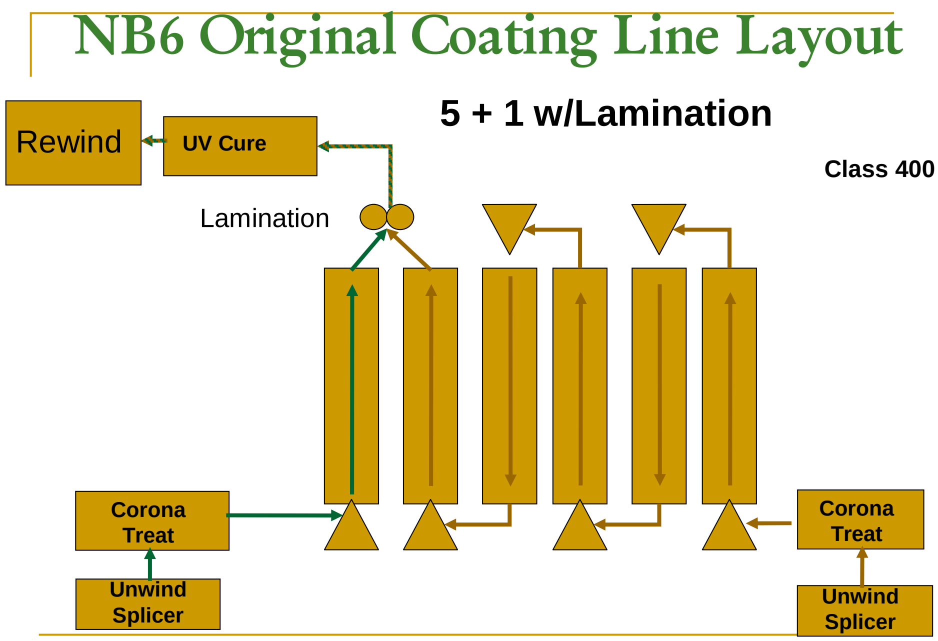

Figure 3

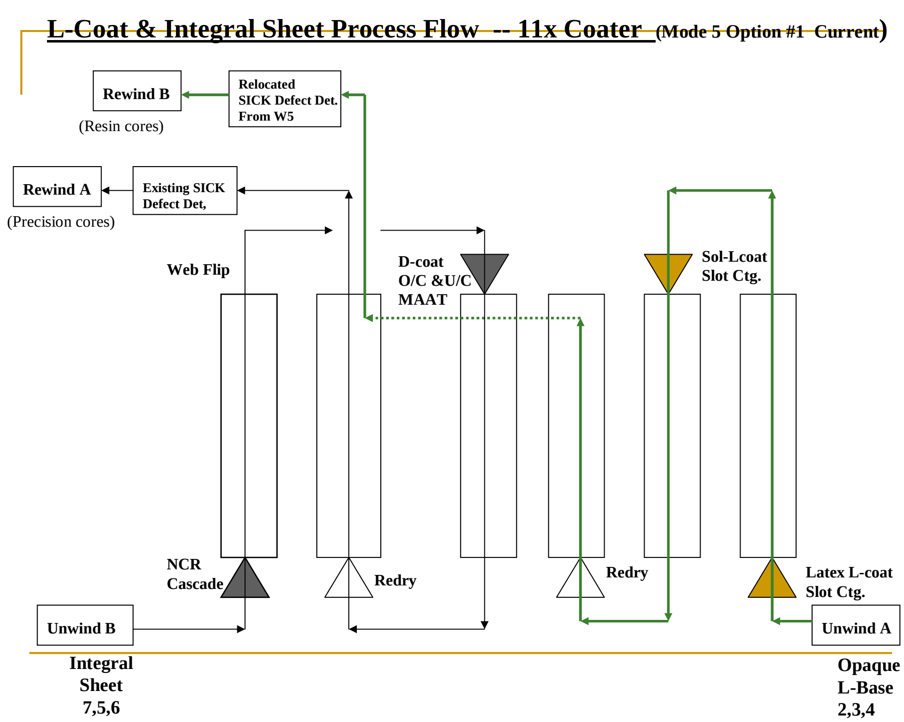

Figure 4

Multilayer Slide Coating

Product Structure

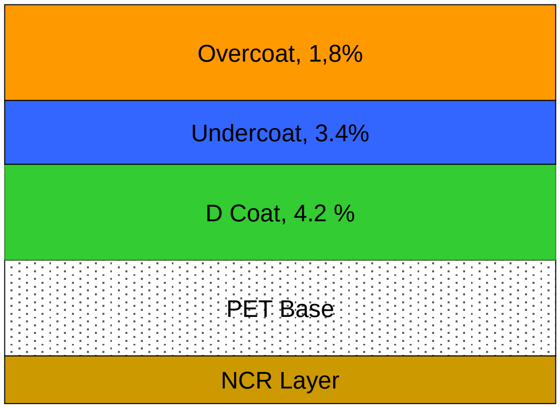

Figure 5

Multilayer Slide Coating

Multilayer Slide Coating Head

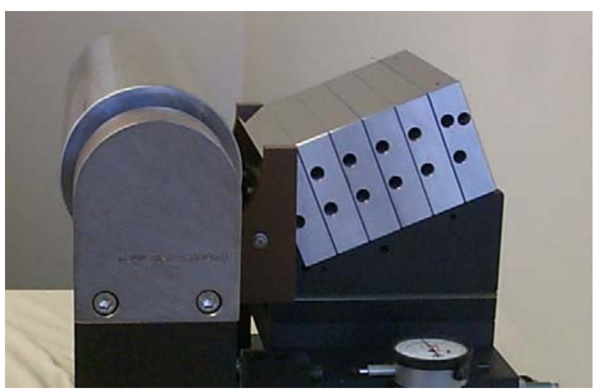

Figure 6

backing roll. As long as the progression down the slide is uniform, there is little if any intermixing between the layers.

As shown in Figure 7, the first production run was plagued with a high level of coating streaks. These streaks were traced to a build-up of the first layer above the first coating slot. This build-up is due to recirculation patterns in the first fluid above the first slot. As the fluid stays in this area, water evaporates, the fluid thickens and starts to dry, and streaks form. This problem was fixed by raising the top plate of the stack, which forms the top of the slot for the top layer, by 100 % of the slot opening. In this case, the slot opening was 30 mils, so the top plate was set 30 mils above the slide face. As seen in Figure 7, a significant reduction in streaks was seen with this modification. This modification is shown in diagram form on the left side of Figure 8. The original set-up is shown in diagram a), and the modification in diagram b). An alternate approach reported in the literature is shown in diagram c), but this approach was not used at Polaroid.

A second important element of multilayer slide coating head set-up is illustrated in Figure 8, namely the radius of curvature of the edges where the fluid-air interfaces are located on the slide. On the left side of Figure 8, the red arrow shows the fluid-air interface for the top fluid. The goal is to “pin” this interface at the edge of the upper plate. If this plate has a rounded edge, it is difficult to get a precise “pin” point, and fluid recirculation may result, causing streaks. However, a razor sharp edge may be a safety issue for operators. The recommendation in

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1st Major Issue – Coating Streaks

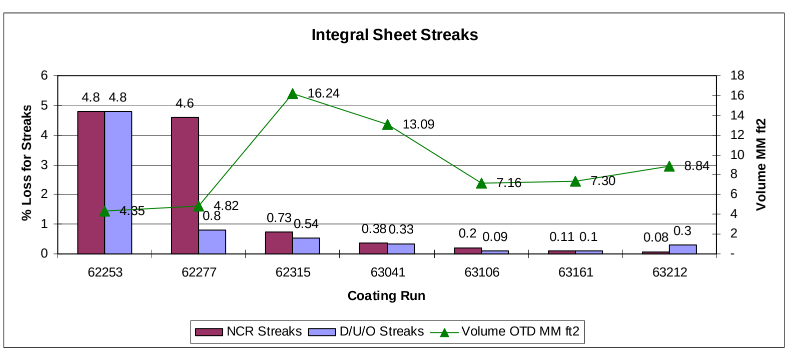

Figure 7

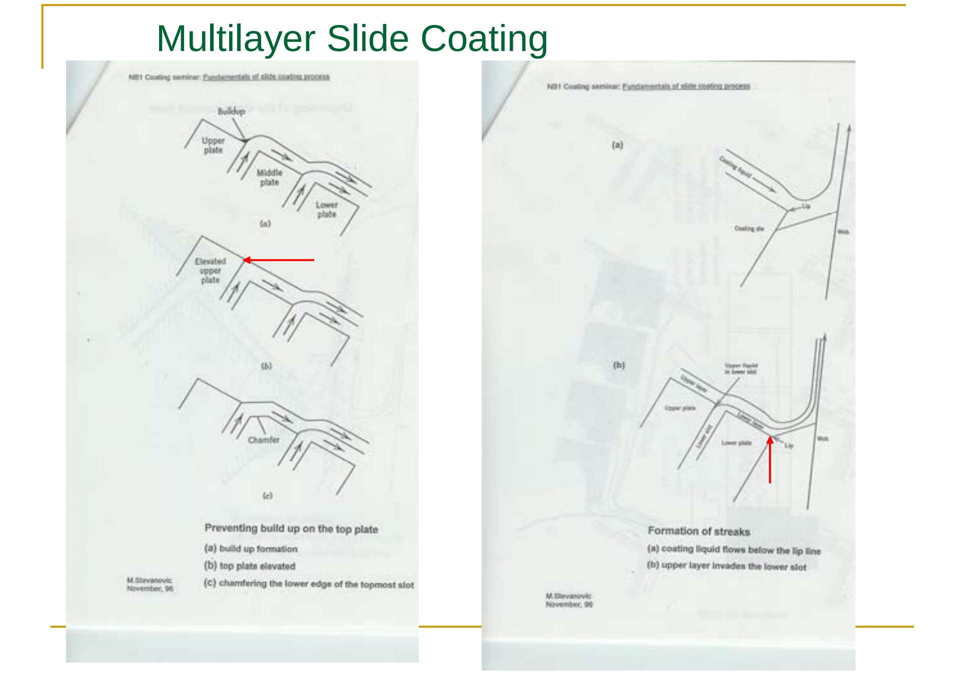

Figure 8

the literature is for this edge to have a radius of curvature of 2-4 mils. On the right side of Figure 8, the same comments from above apply at the point where the coating leaves the slide and moves to the web, namely that the radius of that edge should also be 2-4 mils to better pin the coating to that point (red arrow in Figure 8b). Figure 8a shows the coating not pinned to the end of the slide, which can cause a variety of coating issues. Adjustments to vacuum assist level, web speed, flow rate and concentration, and gap can also be used to alleviate this situation.

A second issue arose a while after the coating streak issue described above, and is shown in Table 1. After several successful runs, a run started with many ”dewet” defects, which are areas of one or more missing coatings. Multilayer slide coatings are particularly susceptible to conditions that cause this defect. Table 1 shows several actions that were taken during investigation of this defect. In this case, the likely suspect was the contamination found in the feed line of the D coat to the slide coating head, shown in Test 9. Once this line was cleaned and the system flushed, the defect level dropped dramatically. The model for the dewets was that the contaminant particulates in the Dcoat line caused areas of lower surface tension that the upper layers could not overcome.

The Clean-In-Place (CIP) process shown after Test 3 was interrupted before finishing, but that was not found until later, misleading the run engineer. Once again, we have proven the fundamental principle that in coating, everything must be done correctly.

<u>2nd Major Issue</u>
<u>Dewets 63304</u>

Test	D-coat	Underct	Overct	Dewets	Comments	
1	Old	New	New	Yes		
2	Old	New	New	Yes	Re-eval-- Many, smaller	
3	Old	New	New	Yes		
Action			**CIP**			
4	Old	New	New	Yes		
5	Old	New	New	Yes		
6			New	Yes	Coated Overcoat Only	
7 (2)	Old	New	New	Yes	Retest of Test #2	
8	Old	New	Old	Yes		
9	**Old**	**Old (Can)**	**Old**	**Yes**	**Last Run old fluids**	Found Riverdale in Gooseneck
10	Old		New	Yes	Same frequency, smaller	D/O only
11	New (Can)	New	New	Yes		By-pass 1332
12	New (Can)		New	Yes	Same frequency, smaller	D/O only, D in U/C slot

Table 1

Several actions which are not recommended were taken in this test sequence, as shown by the red ovals. It is not recommended to have fluids flowing over empty slots. In the above sequence, in one case, two lower fluids were shut off (Test 6), and in two other cases (Tests 10 and 12), the middle fluid was shut off. The danger with this line of testing is in possible interactions between the fluids in the coating slots, where contact time can be much longer than on the slide.

<u>Other Learnings – Solution Properties</u>

In this section, significant information for multilayer slide coating other than the equipment set-up will be discussed, specifically solution properties and process conditions. These learnings have come from prior experience and the literature. The most important solution properties for the layers to be coated are: surface tension, solvent used, viscosity, pH, conductivity, and use of a carrier layer.

A layer with a high surface tension on top of a layer with a low surface tension will break up and form islands – not desirable. A top layer with a lower surface tension, even just a couple of dynes/cm, will overspread and maintain integrity over a higher surface tension layer (~5 dynes/cm recommended). Dynamic surface tension is the key measurement. Surfactants and other materials, such as isopropanol, can be used to lower surface tension. Surface tension of the top-most layer is the most important.

The only solvent used in multilayer slide coating the author is familiar with is water. Evaporation of low-boiling solvents can cause disruption on the slide. For viscosity, the fluids in the multilayer slide coating can have different solution viscosities, but should be within an order of magnitude of each other. For pH and conductivity, in general, there is no intermixing between layers. H+ ions will move rapidly between layers with significantly different pHs. Significant conductivity differences between layers may cause H2O diffusion between layers, but ordinarily is not a problem.

A Carrier Layer is usually a dilute version of the layer above it and is the bottom layer being coated. The rheology of this bottom layer is the dominant determinant of the coating window for the whole stack of layers being coated. Using a carrier layer of low viscosity allows wider gap latitude, faster coating speeds, and coatings more stable to perturbation.

<u>Other Learnings – Process Conditions</u>

The most important process condition is the uniformity of temperature of the coating fluids and the coating head. As in slot die coating, the temperature of the coating fluids and the coating die must be equivalent. Differences in temperature between a coating fluid and the coating die will result in variations in viscosity. For H2O, 1^o change in T will result in a 2% change in viscosity (Perry's), and result in a similar change in coverage. Temperature variations between fluids will result in changes in the coating die's slot openings, leading to further variations in coverage.

For slide angle, a typical slide is set at 15^o to 30^o above horizontal.

<u>Advantages of Multilayer Slide Coating</u>

There are several advantages that can be achieved by using a multilayer slide coater. Significant increases in through-put can be realized, particularly for single station coaters and multilayer products. Often, multilayer slide coatings can be run at faster speeds, due to the increased wet thickness (assumes sufficient drier capacity). Reductions in spot defect levels are often achieved because the web is exposed to the environment for a much shorter time with multilayer slide coating. Finally, reductions of scratch levels are seen because of reduced exposure. Also, in many cases, scratch resistant-layers can be coated over scratch-prone layers.

Slide Die manufacturers

The following are slide die manufacturers that are members of AIMCAL:

Davis-Standard (Premium Member)
EDI
Premier Dies
Yasui Seiki

Trial Locations

Before spending hard-earned capital dollars on a slide die, the author recommends doing a trial or two, utilizing the actual fluids or close physical surrogates. The following AIMCAL companies advertise the capability to do slide die tests on your fluids:

Davis-Standard (Premium Member)
EDI WetWare
Faustel (Premium Member)
Kroenert (Premium Member)
Polytype (Premium Member)
Premier
Yasui Seiki

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