Cotton/Polyester Dye Migration: A Practical Analysis

This article originally appeared in the SGIA Journal in 1997. It was a time when the challenges of printing on fabrics that contain polyester was limited to mostly to cotton-polyester blends. We can now look back on those times as the "good old days" with the advent of 100 percent polyester garments in all types of garments, from T-shirts to jerseys to fleece.

At the same time, the quality of the fabric preparation, for both blends and 100 percent polyesters has gone from fairly good in 1997 to quite poor today. There are some good fabric/garment makers who take pride in the quality of the polyester they produce. Unfortunately, these good manufacturers are in the minority. A conservative estimate is that over 50 percent of the polyester that is sold for screen printing is not prepared properly. The dyes are not heat set (or are of such poor quality that heat setting does not help) so that in spite of doing everything possible to prevent dye migration, it still migrates.

This article is still a valid explanation of what a printer has to do to make sure that the print does not bleed/migrate. Keep in mind that I always recommend that any new garment be tested before a production run to see if the quality is up to standards that will allow the printer to produce a quality product. I realize that time is always short when production is due. However, remember that old saying, "never enough time to do the job, but always enough time to do it over — at your expense."

The procedure and care needed to print on 100 percent poly are the same as for blends. However, the inks used are even more capable of blocking dye. Polyester plastisols contain the maximum level of dye blockers that an ink can hold. Low-bleed blends tend to have about half that amount. To be safe, always make sure that you are using low-bleed blend inks on blends (60% poly or less) and poly inks on poly garments (greater than 60 percent poly content).

The causes of dye migration in cotton/polyester fabric are well known. Unfortunately, the practical prevention of migration is often misunderstood by screen printers. Despite a large number of articles and seminars on the subject, troubleshooting this problem remains one of the most common questions to hotlines, message boards, and even to SGIA.

Having been "burned" by this problem in my own shop, I am keenly aware of the cost and difficulties associated with printing dark cotton/polyester shirts. Everyone knows that darks are the problem, especially those with red-shade dyes. Other colors — such as black and navy — can also create problems, but reds are the biggest culprit.

I decided to undertake a practical test of dye migration on two of the most common

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"bleeders." The shirts are from two of the largest mills; one promotional grade and one premium grade 50/50 cotton/polyester T-shirt. Both shirts chosen were, of course, red.

The Setup

The test was conducted in the Specialty Graphic Imaging Foundation (SGIF) laboratory. The equipment used was:

- M&R Gauntlet Revolver
- M&R Infrared Flash
- Lawson Omega Dryer

Two different, major brand "low-bleed" white inks were used. One was a brand new gallon bucket and the other was a three-year-old, half-empty bucket. In both cases, no modification was made to the ink, other than stirring it well before loading the screen.

The screen was 49 threads per centimeter (125 threads per inch), 70 micron thread, monofilament stretched to 25 newtons per centimeter on a retensionable frame. The screen was coated with direct emulsion 2x2 coats and exposed properly. The squeegee used was a 70/90/70 dual-durometer laminated type set at an angle of 25 degrees from vertical.

The ink was single stroked, flashed and printed a second time to duplicate the most common method of printing white on red fabrics. The individual parameters of temperature and dwell were the variables of the test.

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My goal was to answer the following questions:

1. Are flash temperature and dwell the keys to avoiding dye migration?
2. Are dryer temperature and dwell the keys to avoiding dye migration?
3. Is "pre-cooking" shirts in the dryer away to avoid dye migration?
4. Is the age of the low-bleed white ink a factor in dye migration?

The Principle

Dye migration occurs when the dye on the polyester threads is heated to a point where it sublimates — when the dye reaches a temperature high enough to cause it to go directly from its solid form to a gas. When it does, it becomes free to go somewhere else. It condenses back to a solid, but it is not bound to a fabric fiber.

Unfortunately for textile printers, this free dye loves plastisol. Plastisol acts as a solvent through which the dye is free to move.

The Test

There were 12 shirts of each brand: "A" and "B." Each shirt was numbered 1–12 on the right and left sides, then cut in half vertically. This was done so that each ink brand could be tested on each shirt without having to run the shirts through the dryer multiple times, which may have adversely affected the test.

The goal was to use three different platen temperatures combined with two different temperatures and durations for

Chart A: Dye Migration Test Parameters

	Target			Actual				
				Platen	Flash		Dryer	
Sample	Platen	Flash	Dryer	Temp	Temp	Dwell	Temp	Dwell
1	cold	correct	correct	21°C/70°F	510°C/950°F	6 sec.	171°C/340°F	38 sec.
2	cold	correct	high	21°C/70°F	510°C/950°F	6 sec.	186°C/367°F	44 sec.
3	cold	high	correct	21°C/70°F	538°C/1000°F	9 sec.	171°C/340°F	38 sec.
4	cold	high	high	21°C/70°F	538°C/1000°F	9 sec.	186°C/367°F	44 sec.
5	warm	correct	correct	38°C/100°F	510°C/950°F	5 sec.	171°C/340°F	38 sec.
6	warm	correct	high	38°C/100°F	538°C/1000°F	5 sec.	186°C/367°F	44 sec.
7	warm	high	correct	38°C/100°F	510°C/950°F	9 sec.	171°C/340°F	38 sec.
8	warm	high	high	38°C/100°F	538°C/1000°F	9 sec.	186°C/367°F	44 sec.
9	hot	correct	correct	49°C/121°F	510°C/950°F	4 sec.	171°C/340°F	38 sec.
10	hot	correct	high	49°C/121°F	538°C/1000°F	4 sec.	186°C/367°F	44 sec.
11	hot	high	correct	49°C/121°F	510°C/950°F	9 sec.	171°C/340°F	38 sec.
12	hot	high	high	49°C/121°F	538°C/1000°F	9 sec.	186°C/367°F	44 sec.

both the flash and dryer. I also wanted to conduct the test with platens at room temperature, warm, and hot. I wanted each of these platen temperatures to have three samples that were flashed properly and three that were flashed excessively. And then, the finished shirts were either cured correctly or overcured. Chart A outlines the test temperatures and durations.

Half of the samples were run with the first ink; then the ink was changed and the other half of the shirts were run with the second ink. Care was taken to make sure that the matching "halves" were subjected to the same conditions to make any differences caused by the ink apparent.

After this main test, samples #1 and #12 from each shirt type were used for a test of the practice of preheating the shirts before printing. The shirts were flipped to the unprinted side and run through the dryer at the "hot" settings from the previous test. These shirts were next printed on the second side with the same image, duplicating the previous conditions. Sample #1 was printed on a cold platen with proper flash and dryer settings, and sample #12 was printed on a hot platen with high flash and dryer settings.

Chart B

	Ink X		Ink Y	
Sample	Shirt A	Shirt B	Shirt A	Shirt B
1	●	●	●	●
2	●	●	●	● ●
3	●	●	●	●
4	●	●	● ●	● ●
5	●	●	●	● ●
6	●	●	●	● ●
7	●	●	●	● ●
8	●	●	● ● ●	● ● ● ●
9	●	●	●	● ● ●
10	●	● ●	●	● ● ●
11	●	●	● ●	● ● ●
12	● ●	● ● ●	● ● ● ●	● ● ● ● ●

● = no bleed
● ● = minor bleeding
● ● ● = moderate bleeding
● ● ● ● = heavy bleeding
● ● ● ● ● = extreme bleeding

Results

The test results were not immediately apparent. As is the case in the real world, dye migration does not always happen immediately. The shirts were allowed to sit for two days and then examined. Visual inspection was followed by spectrophotometric analysis. Chart B shows the results of the visual test.

The visual results show several things that can be valuable to screen printers. First, some inks perform better than others. In our test, we used two inks on the different halves of the same shirt. Each sample was subjected to identical conditions. Overall, one ink fared much better than the other. Ink X did a much better job of preventing dye migration — even when it was subjected to extremes of platen, flash, and dryer temperatures. Ink Y performed well when all temperature conditions were closely watched, but failed to block dye migration when the temperatures were pushed.

An interesting note about the ink is that Brand X was the older, well-used container of ink. This fact would signify that the age of the ink may not be an important factor in preventing dye migration.

The second thing that the results substantiate is that excessive dryer temperature and dwell are a more significant factor in dye migration than excessive flash temperature and dwell. That is not to say that excessive flash temperature and dwell are not important; it says, instead, that even if you have a flash set too high or too long, you are less likely to have severe dye migration than if you run your dryer too hot.

The most dramatic result achieved was with the "pre-heat" test. It has long been supported by various people in the industry that dye sublimation and migration can be reduced — and even eliminated — by running shirts through a hot dryer before printing them to rid the excess dye. While this practice may release the dye from the polyester threads, it does not leave the garment. Its dye molecules are just unattached or unbound and even more readily available for migration. When this test was conducted on four of our shirts, the color shift in the white ink occurred very quickly. It was even detectable as the shirts exited the dryer. Even the shirt run at the proper settings for flashing and curing shifted in color on the pre-cooked shirt.

Spectrophotometric Analysis

To verify the visual analysis, selected samples were then tested using a spectrophotometer to actually measure

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Chart C

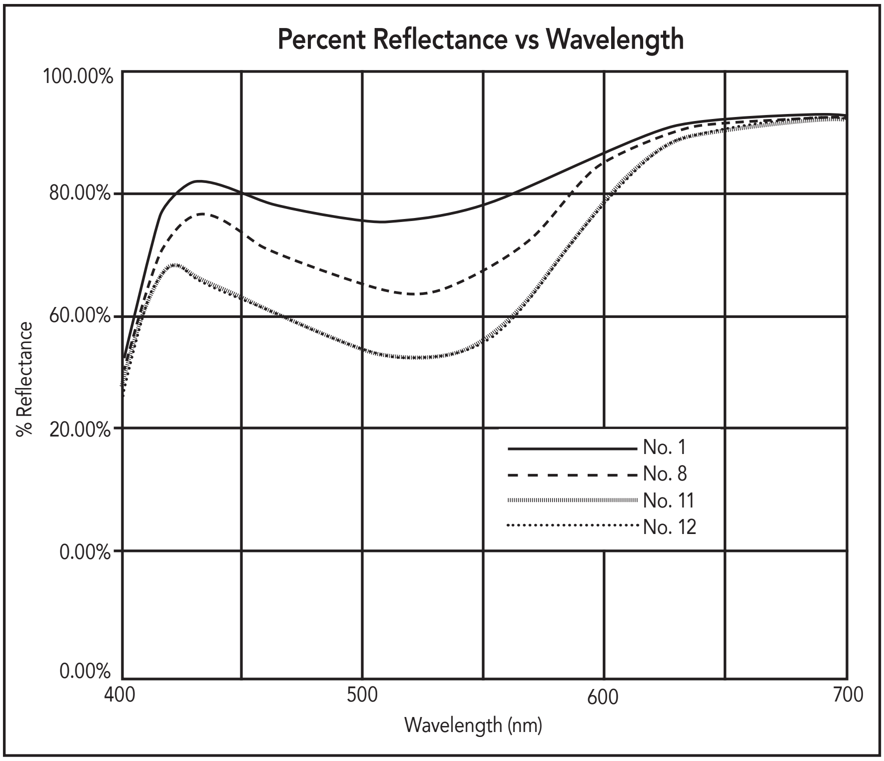
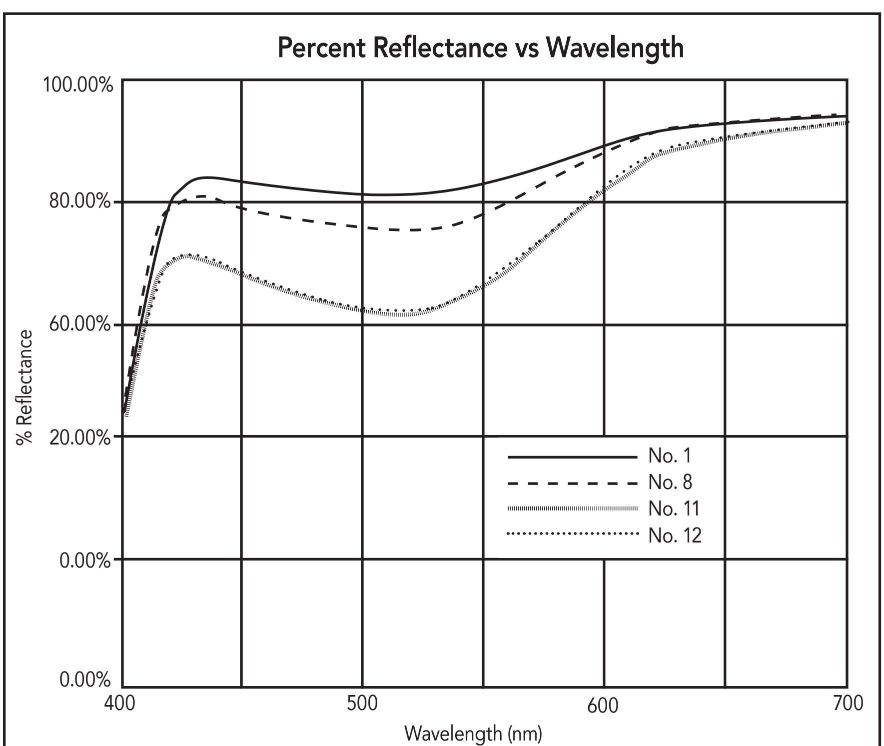


Chart D



the color shift in the white ink. In the interest of time and to simplify the output, we only tested the best and worst samples in each group. We used sample #1 from each set as the base line, assuming that it looked the best and was the maximum achievable quality possible for each ink/shirt combination.

The spectrophotometric results confirmed the visual analysis. In each set of shirts, samples 11 and 12 showed the greatest amount of color shift. Sample 8 was also tested and showed a moderate amount of shift with Ink Y but very little with Ink X. Chart B is an example of the results achieved. Charts C and D represent the spectrophotometric results. Both charts are a measure of percent of reflectance versus wavelength. The whiter the ink film, the higher the percent of reflectance.

Chart C is for the promotional grade shirt using Ink X. Chart D is for the premium weight shirt using the same ink. The top line on each chart is the baseline sample #1. The other lines are for samples 8, 11, and 12 (descending order).

It can be ascertained from these charts that the color shift was greater for the promotional grade shirt than for the premium grade one, even though the ink was the same. This result is not surprising. The better grade shirt has a smoother and more consistent printing surface. The ink deposit is therefore better than that on the promotional grade shirt. This does not mean that the premium grade shirt will not bleed; it just means that you can achieve a better ink film consistency on a premium grade fabric.

Now What?

Testing confirmed that proper ink and practices can overcome difficulties in printing fabrics susceptible to dye sublimation and migration. No amount of effort on the part of ink manufacturers to make a foolproof white can compensate for a screen printer who does not pay attention to the proper way to print 50/50 fabric. The following practices will give any printer a better chance for printing without dye sublimation and migration.

The Ink

Use a high-quality, low-bleed white. Do not modify the ink without checking with the manufacturer. (If you modify an ink, you run the risk of diluting its low-bleed characteristics.)

Never use an ink that is new to you on a big job. When testing your whites, do so in a method similar to what I have done in this study. Subject a few of your samples to harsh conditions and make sure that the ink holds up. Only when you are certain that you are using a white that will allow for a certain amount of variation in printing conditions should you use it on a regular basis.

The Flash

The flash is a wonderful invention. It has made printing on dark garments a lot easier. However, it is not a set-and-forget tool. The flash will steadily warm the platens. As it does, the ink film requires less energy from the flash to do its job because it is already warmed by the platen. Flashes should be adjusted throughout the course of a print run to ensure that you are using the minimum amount of energy necessary to surface cure the ink.

As you can see from this test, the flash dwell dropped one second for each 11–17 degrees Celsius (20–30 degrees Fahrenheit) increase in platen temperature. If you cannot change the dwell, you need to drop the temperature.

If you are using quartz flashes instead of infrared, you have the added flexibility of being able to adjust the dwell of the flash without having to adjust the dwell of the print cycle. Quartz flashes, when used properly, will also decrease the amount of heat build up in the platens.

Manual printers need to be even more watchful of their flashes. On the basic flash units, dwell times are controlled by the pace of the printer. As platens heat up, it is necessary for printers either to raise the flash, or work faster. Manual flashes that have an automatic rotation feature can be adjusted to shorten the dwell time — a big advantage.

The Dryer

The dryer needs to be set to cure the ink, not cook the shirt. The ink film needs to reach its optimal cure temperature (usually 166 degrees Celsius, or 330 degrees Fahrenheit) but no more. If you test your dryer and find that the surface of the shirt is exceeding 177 degrees Celsius (350 degrees Fahrenheit), you are asking for trouble. The polyester dyes begin to sublimate at approximately 182 degrees Celsius (360 degrees Fahrenheit). Once they do, you cannot reverse the process. If the dyes sublimate, they will migrate in the presence of plastisol ink.

Don't Forget to Test

Any job you print should be tested for quality. Quality is not just the image registration and appearance, but is also the color fastness and ink film durability. In most cases, washing a sample from each run will give you a good indication of these factors. However, with polyester fabrics, it is a good idea to also test them by subjecting them to accelerated age testing. There are several ways to accomplish this aging. The most common method is to place a sample from the print run on top of a very warm dryer for 24 hours. A second method, one that I have used quite successfully, is to place a sample on the dashboard of a closed-up car on a sunny day. If, after a few hours, there is no dye migration, the likelihood is good that you will not get any.

Mike Ukena has 28 years of experience in the industry. He previously served as the Director of Education and as part of the Technical Services Department with SGIA. As a frequent speaker at many specialty imaging events, he is currently a member of the Academy of Screen Printing and Digital Technologies, and is the Regional Sales Manager for Union Ink Company.