THE SECOND C:
The Truth About Color Revisited

By Keith Hoover

In 2007, I presented this paper at the AATCC International Conference and Exhibition (IC&E) to provide insight into the nature and validity of the lab dip color approval process in place at one large retailer. The practices documented herein predate the Color Accreditation Program (CAP) covered in the Primum Mobile series of articles, however, they are similar to, if not better than, most color management processes in place today. The intervening sixteen years have not yielded much improvement in our industry. Thus, this paper is not an indictment of any organization. Rather, it points out that the "emperor of visual color approval" has no clothes, a somewhat ironic charge to make about fashion brands.

At a time when "speed to market" is more important with each passing financial quarter, it is surprising that the processes identified herein are tolerated. However, color is still viewed by many as a "mystery," and few folks have been willing to tackle a product attribute so visible to the customer. There is an acknowledgement that current processes are slow and inefficient, but few are equipped to implement solutions.

Successful color management is a function of numbers, math, and metrics. These are attributes with which few currently involved in color are comfortable. In fact, the "current wisdom" in retail product management still views color approval as closer to "creativity" than process control. Hopefully, this article will help to serve as a catalyst in changing that perception.

A BRIEF HISTORY OF COMMERCIAL COLOR MANAGEMENT

Color has been described as the blood that brings life to the flesh and bones of a product. Indeed, color runs through the processes of design, development, pre-production, quality assurance, and ultimately is the primary and most apparent product attribute perceived by customers. The elements of commercial color management thus span the entire product lifecycle and lay the foundation for specification and matching.

Color Standards

The Design department is responsible for selecting and specifying product colors. As such, the selection of a color standards provider is of primary importance since it has a direct bearing on a designer's ability to develop products that generate high sales volumes. Given the importance of color to product appearance, it is necessary for designers to have access to a color system with a large gamut of shades appropriate for each product line, coordinating as desired across hard and soft lines. Since, as Dan Randall [1] stated, color begins at conception, it is all the more important that the right colors are chosen—not only from an aesthetic point of view, but from a technical angle, as well.

Colors must be achievable on the materials of each product. Various materials use specific types of colorants that change appearance under different types of light (store lighting and daylight, for instance). So, the first crucial step in color specification is selecting a color that can be matched on different materials in different lights. Color standards that meet this criterion are referred to as "engineered standards," since they are ostensibly formulated to facilitate the production process.

Color Matching

Manufacturers that compete successfully in today's global market use digital color formulation, match correction, and QC software paired with spectrophotometers to automate what was once considered the "art" of color matching. *Color by numbers* is the current best practice.

Prior to 1960, no commercially feasible technology was available for this purpose. Such equipment was only in place in research institutes and universities, even though the

underlying logic of mathematical color matching had been devised in the 1930s. Some clunky technology involving mainframe computers and teletype machines crept into the mills in the 1960s, but it wasn't until the advent of the personal computer that color by numbers could become commercially practical.

This new process allowed color to be measured on a spectrophotometer to capture spectral data (sets of 31 numbers), thus producing a "color fingerprint." Once reduced to numbers, various metrics could be applied to measure the difference between sets of colors. Coats UK and the Society of Dyers and Colourists (SDC) in the UK developed the CMC color difference equation that allowed for more consistent, objective color match decisions than could be rendered by people in the profession. It established the necessary correlation between the visual appearance of color and its corresponding numbers. This method continues as the industry standard today.

In the 1990s, Marks & Spencer (M&S), led by Chris Sargeant, became the first retailer to implement color technology to communicate spectral data and evaluate lab dips digitally. Sargeant's process eliminated the use of physical color swatches and visual color matching for about 80% of the fabric used in M&S garments. The result was a significant reduction in time required to match color, a tremendous improvement in the quality of the color match, and the ability to better coordinate consistent color across products.

Due to the expense and technical nature of the process, other retailers were slow to embrace the total process, implementing bits and pieces instead. Target, a notable exception, launched an integrated, all-encompassing global process in 2001 and led the charge in "speed to market" in the US. Target also adopted color technology to better coordinate matching between textiles and plastics.

"Big Ol' Department Store" (BODS) attempted a similar approach, placing color instrumentation in strategic locations around the world.[2] The process differed, however, since it continued to place primary emphasis on visual assessment over numeric evaluation. There had been considerable apprehension about relying on the numbers. However, a significant volume of data was collected that linked visual color match decisions with corresponding spectrophotometric measurements. An analysis of this data provides the truth about color.

THE BODS DATACOLOR TOOLS DATABASE

Approximately 5,300 sets of color measurements were stored in BODS's Datacolor Tools database from December 2004 to September 2005. These records captured color measurements of lab dips linked to 224 different Archroma colors throughout the color gamut. Although a small percentage of records were missing, and a few records contained bad data due to typing errors, this dataset is nonetheless more than sufficient for analysis.

Correlation Between Visual Appearance and Digital Analysis

A fundamental requirement of a digital color process is that it must judge color the way that people do. The CMC color equation figures the overall color difference between a color standard and a proposed match in a unit called Delta E (DE_{CMC}). A commercially acceptable color match has a value of no greater than 1.00—the lower the value, the better the match.

It is important at this point to distinguish between "perceptible" and "acceptable" color difference. A perceptible color difference is one that is so subtle that one has to look quite hard to see it. Most people would overlook it. Those involved in the color profession are more likely to be able to spot these tiny differences. Occasionally, in stressful conditions, some might even see color differences that don't exist. Perceptible color difference is irrelevant in commercial color control, since attempting to correct it adds no value in the customer's eyes.

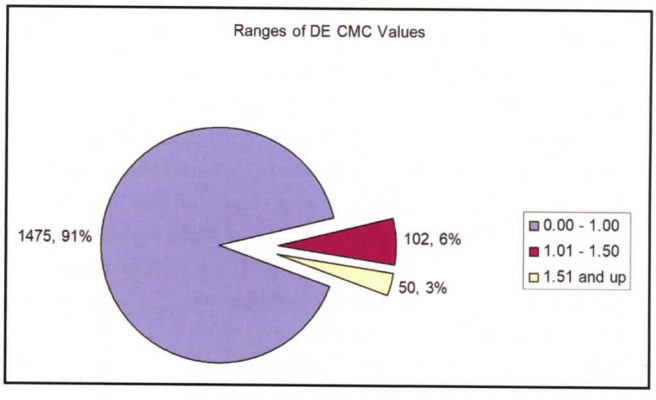


Figure 1. Ranges of DE_{CMC} values.

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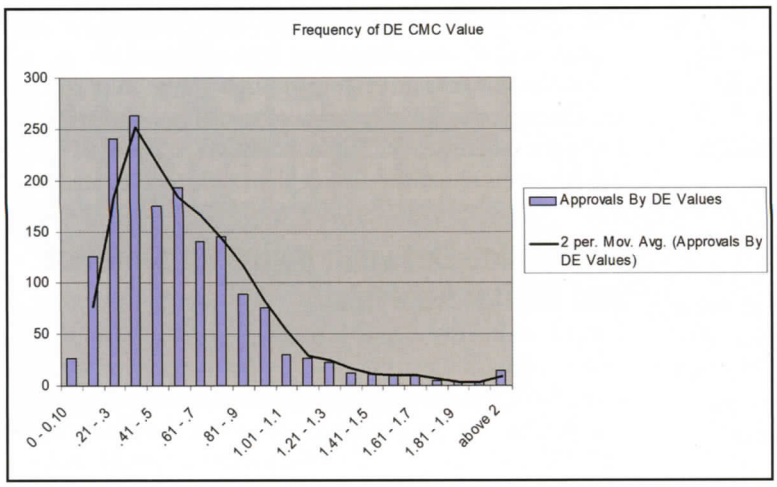


Figure 2. DE_{CMC} frequency for visual approvals

Acceptable color difference, on the other hand, is a balance of the amount of color difference that a normal customer is likely to overlook or see without offense and the amount of color difference that can be controlled by a competent manufacturer from lot to lot. Acceptability may change, due to the nature of the product (coordinates vs. one-offs). However, it is important to stipulate that a tolerance for acceptability cannot be set lower than a supplier's ability to consistently match the color over time in production (process capability). Doing so leads to high levels of seconds, late deliveries, and loss of profitability.

Whether done visually or digitally, there must be some idea of acceptability expressed as a consistent tolerance in order to make color pass/fail decisions. If the color difference metrics that correspond to visually determined pass/fail decisions are consistently under 1.00 DE_{CMC}, then it can be concluded that the metric is valid. Furthermore, if there is very little variation in the numbers that are used to average a large set of these measurements that correspond to visual pass/fail decisions, then that adds reinforcement. However, if the numbers corresponding to visual passes yield high or inconsistent numbers, then either the equations are invalid or something is wrong in the way that the colors were captured (spectrophotometer problems, for instance). Recall, that the industry-accepted value for acceptable color difference is 1.00 DE_{CMC}.

Strong Correlation

The BODS Datacolor Tools data provides convincing evidence that there is, indeed, strong correlation between the visual pass decisions and the corresponding digital numbers. There are 1627 lab dips that were visually approved. The average color difference is 0.57 DE_{CMC} in store light (known as UL3000) and 0.77 in daylight (known as D65). Of all visual approvals, 91% measure 1.00 DE_{CMC} or less (Figure 1). Six percent measure between 1.01 and 1.50 DE_{CMC}. Only 3% measure above 1.50 DE_{CMC}.

Due to textural surface variations, some fabrics are difficult to measure repeatably. Even if a method is found, sometimes there is poor correlation between the numbers and the visual appearance. Given the variety of textured fabrics used in retail today, it is expected that between 10% and 20% of lab dips cannot be reliably evaluated using only digital data. Reasonable color processes account for these exceptions by requiring visual evaluations for specific, predefined types of fabric.

The BODS Datacolor Tools data are certainly in line with this rule of thumb. Most of the adequately labeled passed lab dips that measure significantly above 1.00 DE_{CMC} are colors on highly textured fabrics.

To further reinforce the numeric and visual correlation, the average color difference of all visual approvals measuring 1.00 or less is 0.48 (UL3000) and 0.69 (D65) DE_{CMC}. The precision of the color matches in the BODS Datacolor Tools database is truly amazing as is the near perfect correlation between the color difference numbers and visual appearance. In fact, Figure 2 indicates that there is a tendency for BODS Colorists to approve lab dips most frequently when the color difference is between 0.21 and 0.40 DE_{CMC}. Herein, however, lies a significant problem.

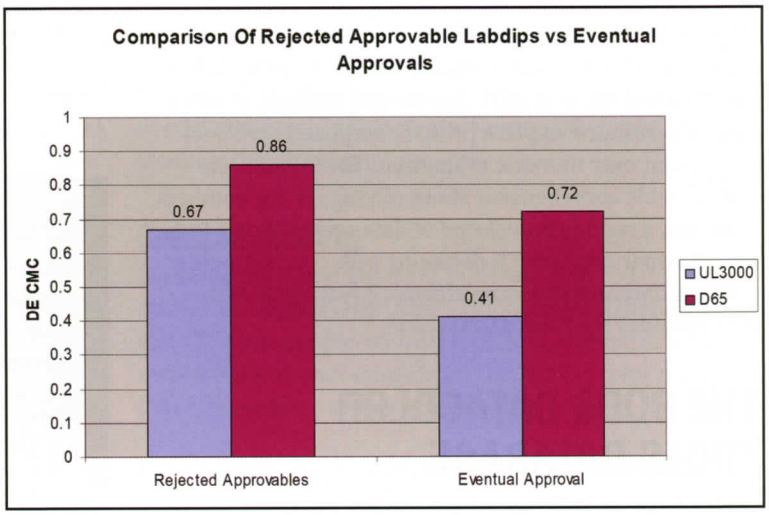


Figure 3. Initial rejections compared to eventual approvals.

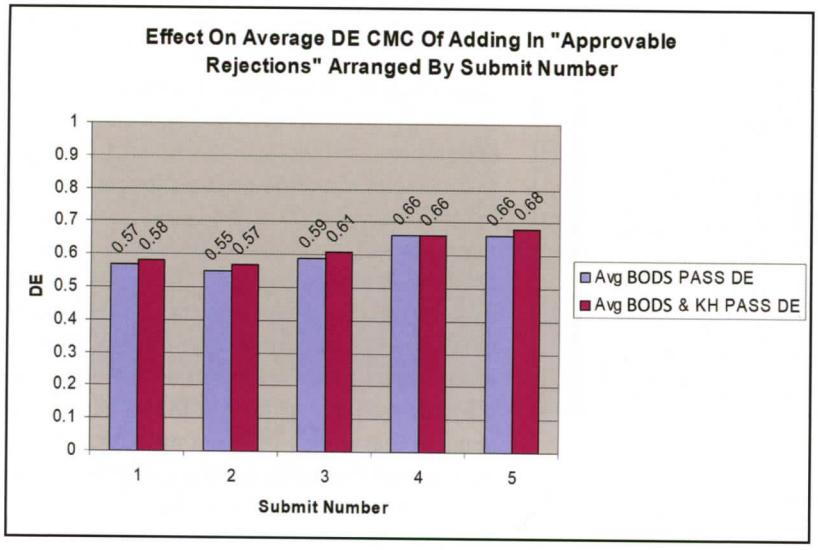


Figure 4. Adding in "approvable rejections.

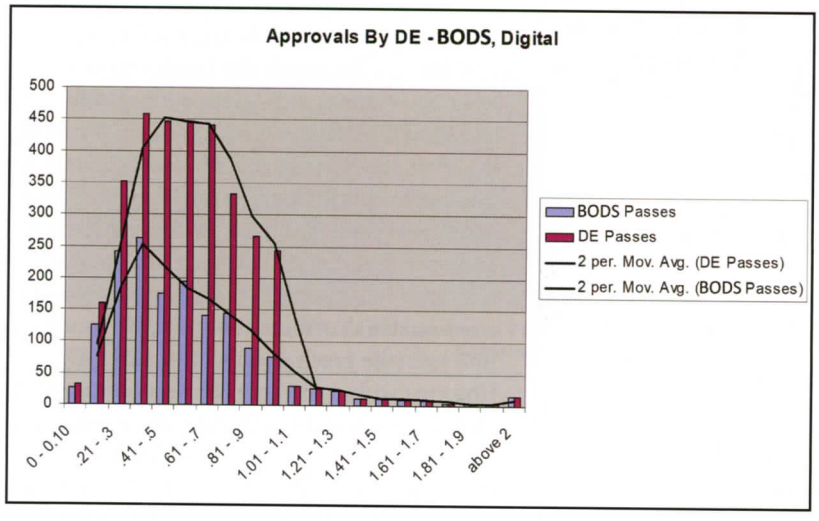


Figure 5. Visually approved and digitally acceptable labdips.

Missed Opportunities

Since it has been firmly established that the BODS visual color approvals line up quite nicely with digital color difference best practices, the data can be analyzed from a different perspective. An analysis of all the lab dips measuring less than 1.00 (UL3000) and 1.25 or 1.50 (D65) in the BODS Datacolor Tools database should indicate how well BODS Colorists' perception of color match acceptability compares with the industry guidelines. Given the nature of the light sources used to evaluate color, some retailers allow a higher color difference in the secondary light (daylight for BODS). Both approaches will be evaluated. The tighter tolerance (1.00/1.25) will be referred to as (A) and the wider tolerance (1.00/1.50) will be referred to as (B).

BODS visually approved 1629 out of 5271 lab dips submitted. However, an additional 1606 lab dips within tolerance (A) were rejected. Adding in lab dips that meet the extended acceptability of tolerance (B) brings the total to 1700. It appears that BODS visually approved less than half of the acceptable lab dips submitted. To further investigate the alleged acceptability of the "rejected approvable" lab dips, the eventual approvals of 103 were analyzed. In all cases, the color was eventually matched under a DE_{CMC} of 1.00. The differences are illustrated in Figure 3. In many cases the eventual approved DE_{CMC} values were lower than the initially rejected lab dip, although the improvement was insignificant (see "Purpose Of A lab dip" below).

Furthermore, the impact on the average DE_{CMC} of all approved lab dips would barely budge, if all "approvable rejections" were added in, as shown in Figure 4 (note that only UL3000 DE_{CMC} values are plotted).

Revisiting the graph describing the frequency of lapdip approvals by DE_{CMC} increments and adding in data for the "rejected approvable" lab dips provides a good insight into what is happening. Figure 5 compares BODS approval tendencies (the lower line skewed to the left) with how all approvable lab dips—BODS visually approved lab dips plus "rejected approvable" lab dips meeting criteria (A) and (B).

While the combined BODS/"rejected approvable" lab dip population takes on a typical bell-shaped curve distribution, the BODS approvals are skewed to much lower DE_{CMC} values. BODS visual approvals are much tighter than required. Had the BODS approval population been skewed to the right—towards higher DE_{CMC} values, then it could be argued that the Archroma-supplied spectral data does not accurately define the colors. Such is not the case here. Independent mills located around the world were able to consistently and precisely identify and match colors when submitting lab dips for approval matched to the same Archroma color standard. BODS colorists appear to have a different idea of what color matches are considered acceptable. It appears that BODS colorists have blurred the lines between acceptable color difference and perceptible color difference.

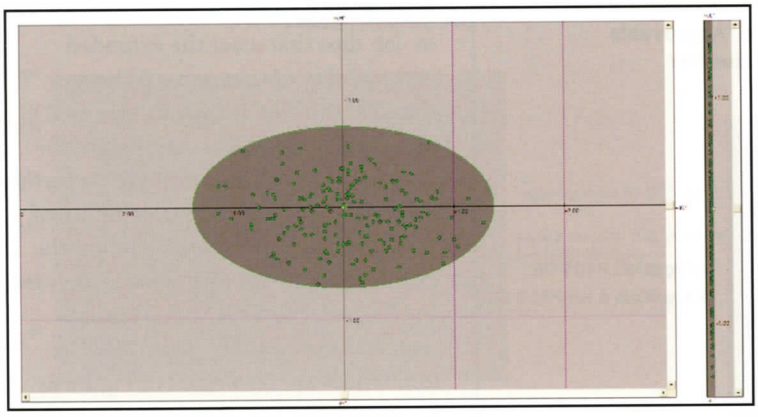


Figure 6. The DE_{CMC} acceptability ellipsoid.

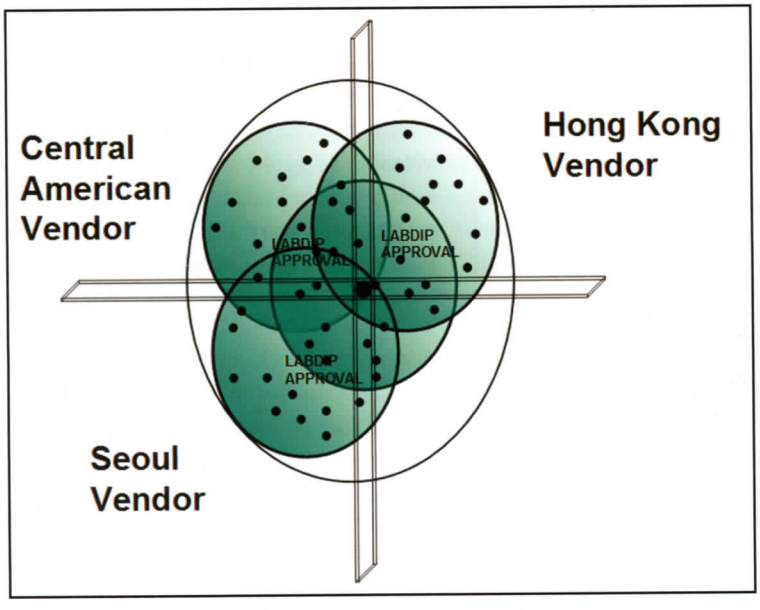


Figure 7. Production matched to lab dip approvals.

Since many dyes are available for use, the dyer must select the right dye combination that allows him to 1) acceptably match the color standard in the two specified lights, 2) meet the required fastness specifications, 3) provide as little color variation within a lot and from lot-to-lot as possible, and 4) meet his budget. Any mill that can consistently achieve good production dyeing has spent quite a bit of time and money to optimize the correlation of lab dyeings and production dyeings. The more these agree, the less money is wasted on offshade seconds. As long as BODS has sourced vendors that work with good mills, then it can be assumed that mills make good faith efforts when matching color. It is in their financial best interest.

So, how good does a lab dip have to be? The accepted practice is to match a color under 1.00 DE_{CMC}. An acceptable lab dip represents what one—but not all—acceptable production lots should look like. It should be understood, however, that if one particular acceptable production lot is a little green and light, another acceptable production lot will be equally red and dark, but both will be in an acceptable tolerance to the standard. Figure 6 represents a reasonable distribution of multiple production lots (the green dots) within 1.00 DE_{CMC} (the area within the grey ellipse and the vertical grey line to its right) around a given color standard. An acceptable lab dip could plot out like any of the dots within the elliptical color difference tolerance. Good mills are able to repeat to even tighter tolerances.

THE PURPOSE OF A LAB DIP

So, how good is good enough when it comes to approving lab dips? Why go through the exercise? What is the desired outcome? First of all, it is important to understand what a lab dip means to a mill.

Mills dye thousands of pounds of fabric at a time, so they must be able to accurately match a color on the first and all subsequent production lots. The penalty of not matching "Right First Time" is quite expensive, given the cost of fabric. A method was thus devised to scale up the dye recipes used to match colors on small pieces of fabrics to accurately color large pieces of fabric. By calculating the amount of each component dye as a percentage of the weight of the fabric, this objective could be achieved. So, the main point of making a lab dip is to get a starting dye recipe that works in production.

BODS requires that all production that can be digitally evaluated must be corrected back to and evaluated against the original Archroma Color standard. Otherwise, different products matched to the same color standard would vary in appearance, if each approved lab dip supplanted the original Archroma standard. Figure 7 shows what would happen to the color difference of fabric in the same color if each of the three mills substituted its approved lab dip for the original Archroma color standard. Even though each of the approved lab dips was acceptable to the standard, each mill's production drifts away from the original standard if the Archroma standard is not used as the production standard. In the world of global sourcing, establishing a single source of truth for the appearance of a color standard is essential.

So, if the goal of the lab dip is to match within a DE_{CMC} of 1.00, is a tighter match even better? As long as the mill complies with the BODS requirement to use the Archroma

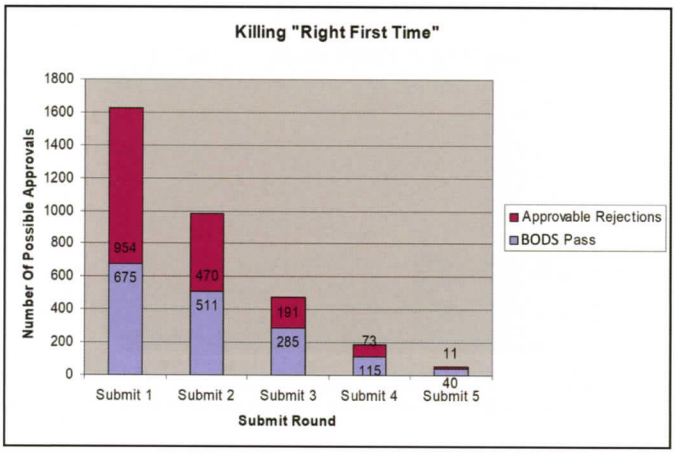


Figure 8. Killing Right First Time (RFT).

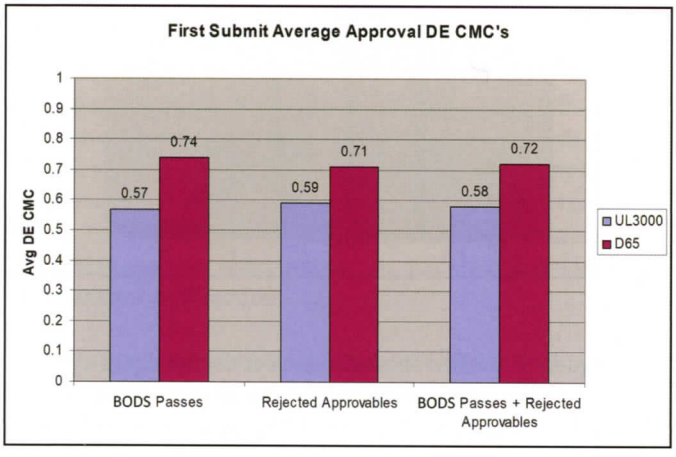


Figure 9. The cost of bad decisions.

standard as the production standard, then any effort to further tweak a lab dip under 1.00 DE_{CMC} is wasted. Time is better spent adjusting production lots closer to the Archroma standard. When a mill moves from a lab dyeing to a bulk dyeing, a slight formula adjustment is frequently required, given the scale of the difference between ounces of fabric and hundreds of pounds of fabric. So, the scaled-up lab dip formula will look slightly different in production. Based on the degree of lab-to-bulk correlation, the color difference will vary. But, a lab dip that measures 0.00 and another that measures 0.99 will both have to be adjusted going to bulk. The extra precision of the better lab dip does not necessarily translate into better production. It's just a better lab dip.

THE COST OF REJECTING ACCEPTABLE MATCHES

The BODS Datacolor Tools data suggest that acceptable lab dips are routinely rejected. This is especially problematic, since the highest number of "rejected approvable" lab dips occur with the first submit. But, as Figures 8 and 9 indicate, the average color difference of first round "rejected approvables" (A+B) is basically equivalent to the BODS approvals. Averaging the data together emphasizes their equivalence.

To calculate the financial impact of "rejected approvables," a cost of $100 (a widely quoted estimate of the cost of a round of lab dips) to the vendor/mill can be associated with each one.[3] This figure only assigns value to the task of creating lab dips. It does not calculate lost time or any other variables likely to harm the vendor/mill.

For All Approvals

- 1606 "rejected approvable" lab dips (A) = **$160,600**
- 94 "rejected approvable" lab dips (B) = **$9,400**
- Total, 1700 (A + B) "rejected approvable" lab dips = **$170,000**

It could be argued that these figures overestimate the financial impact since, if the first round of "rejected approvables" were passed, then there would be a reduced volume of second, third, fourth, and fifth round submits. The impact of "rejected approvable" first round submits can be evaluated as follows.

For First Round Submits

- 899 "rejected approvable" lab dips (A) = **$89,900**
- 55 "rejected approvable" lab dips (B) = **$5,500**
- Total, 954 (A + B) "rejected approvable" lab dips = **$95,400**

Over half of the entire financial impact of "rejected approvables" occurs with the first round of lab dips.

Additional problems stem from rejecting approvable lab dips. First of all, there will be confusion at the mill. After all, how does a dyer "correct" a lab dip that matches the standard? What happens, more often than not, is that the dyer re-submits the rejected lab dip (gasp) as if it were a new one. Not surprisingly, re-submitted failures are frequently approved. This leads to erosion of the credibility of the retail Color Office. Unless retail colorists have a mill background, their reputation is suspect from the start. Rejecting acceptable color matches only reinforces the initial skepticism.

The probability of production-related quality issues increases as the time required to receive a lab dip approval increases. Good dyeing at the mill and construction techniques at the factory cannot be maintained if too

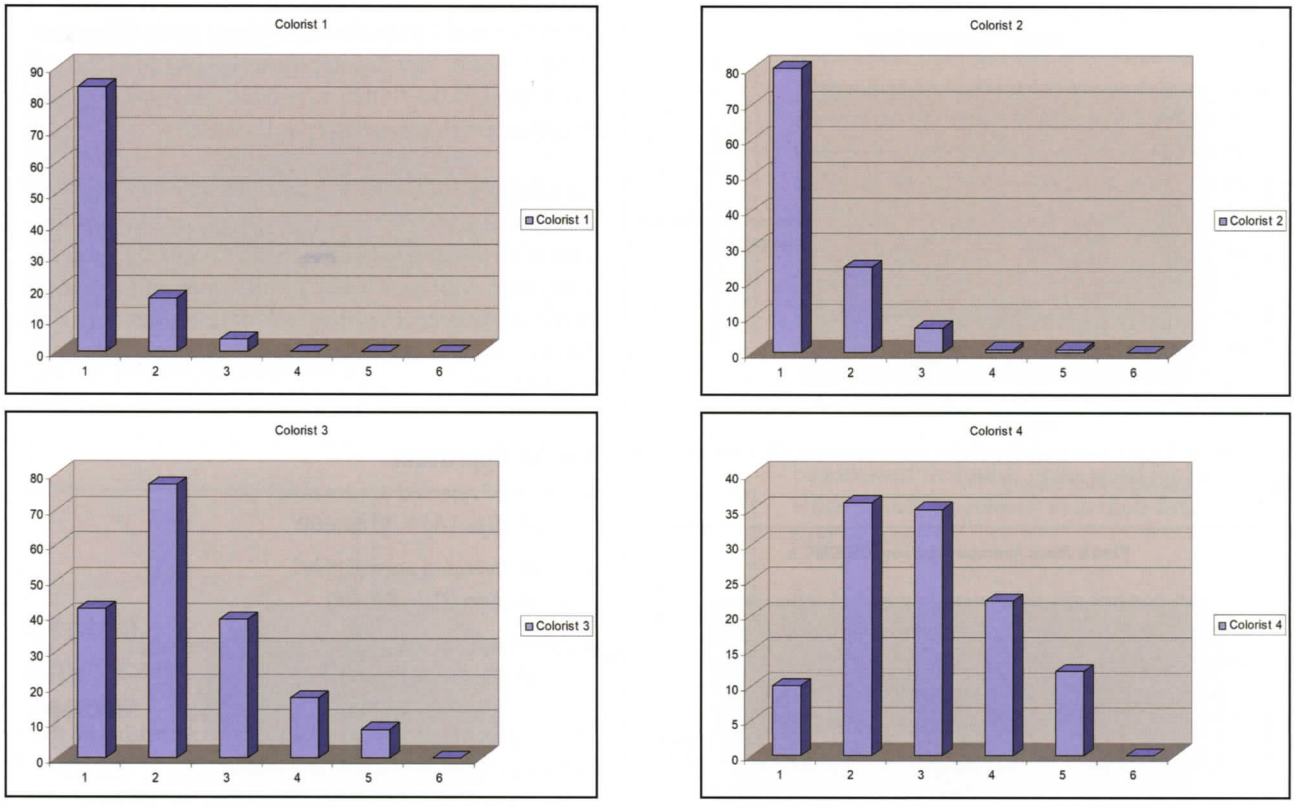


Figure 10. Decision making behavior by colorist.

much time is lost during color matching. Furthermore, air shipping most likely eliminates a mill's entire profitability margin, placing its viability in jeopardy.

A CASE STUDY IN COLOR APPROVAL

A good deal can be gleaned from observing the approval patterns of four BODS Colorists, anonymously (though certainly not creatively) referred to as Colorist 1, Colorist 2, Colorist 3, and Colorist 4. The charts in Figure 10 are based on real data, but the names were changed to protect the innocent (and guilty, too).

Colorist 1 approved 105 colors, Colorist 2 approved 113 colors, Colorist 3 approved 183 colors, and Colorist 4 approved 115 colors. Colorists 1 and 2 approved nearly all approvable lab dips on the first round, while Colorists 3 and 4 held back and awarded approvals later in the game. What is the reason for the discrepancy?

Various discussions with different colorists revealed that factors other than color difference could change a color decision. Colorists are often of low rank in overseas merchandising offices and are thus easy targets for blame if color issues arise in production. For instance, if an order comes in offshade (a production issue), merchandisers frequently (and erroneously) look at the lab dip as a possible source of the problem. There is an assumption that lab dips get better, round to round. Therefore, if a first round approval had gone on to a second round, then it would have been better. It's the colorist's fault! This explains the tendency by some colorists to resist approving lab dips in the early rounds in hopes that a better one will come along later. Many dyers will testify to the fact that the colorists who fit this "wait and see" profile are often approving the same lab dips on round 2, 3, and 4 that they rejected at submit 1. The lesson here is in line with the Right First Time philosophy.

However low on the totem pole colorists might be, they have figured out a means of avoiding the wrath of merchandisers. Rather than approve good color matches on the first or second round, some will wait until a "Best Can Do" (BCD) approval is required. Those that follow this practice can thus avoid the merchandisers' blame if production issues arise, since they were "forced" to issue a BCD due to timing ("It's not my fault!").

The Silver Lining

The problems outlined in the preceding sections are serious, but easily remedied, since they involve training and adherence to a better SOP. Given the high turnover in the various BODS Overseas Color Offices, it is not surprising to see problems of this nature related to a color process

relying on visual assessment, a skill that can only be developed through extensive experience over time. It is amazing to see the match quality and consistency of so many lab dips from so many mills. This is a testament to BODS' sourcing strategy and mill matrix. It is further interesting to note the consistency of color measurements at so many different locations.

The big news here is that the Archroma promise of better, faster matches is indeed occurring. It would be reasonable to infer that there are a high percentage of mills matching strictly to the spectral data. They are submitting lab dips with low DE_{CMC}'s indicated both at their mill and the BODS Color Office.

One final set of statistics. The average DE_{CMC} (UL3000) for every lab dip submitted, regardless of the pass/fail judgment for rounds 1—5 is as follows: 1.05, 0.97, 0.92, 0.90, and 1.01. In fact, the average DE_{CMC} for all lab dips stored in the BODS Datacolor Tools database is 1.00—on the nose. Granted, averages cover a lot of ground, but to have a value this low is indeed amazing. It takes very low numbers to offset very high numbers. Something is going right. The exciting promise is that radical improvements in timing and cost reduction can be quickly realized with adjustments in direction.

When consulted on this project, Chris Sargeant, formerly with Marks & Spencer, provided a perspective gathered from his many years of experience and success on this very topic.

"I think you have to persuade your colleagues to look at using strict data. Only pass and fail with standard conditions and procedures versus the present manual approach. Note relative time taken, delays to production in the manual method, costs incurred, etc. and look at the resultant continuity achieved in bulk as a result (and the smiles at the mills with the data approach, increased productivity, lack of hassle etc.!). We did this [over 25] years ago and never looked back! It is true that some fancy fabrics or structures may be difficult to measure—perhaps about 20%—but you can get huge benefits by applying 21st century technology to the 80% which can! This also creates time to handle the difficult cases by exception."

GOOD TO GREAT

In his book, *Good To Great*, Jim Collins states, "You could have taken the exact same leading-edge technologies pioneered at 'Good To Great' companies and handed them to competitors for free, and the competitors still would have failed to produce anywhere near the same results." Retailers in general have the opportunity to implement a valid color approval process that will reduce cost and increase speed. We must take that step and execute best practices immediately. That is, if we're not scared.

And finally, the first person in the UK to have electricity available throughout the house used the new technology only to power one device… to light her candles. Like the electricity in that woman's home, most retailers' current approaches to color approval have the potential to do so much more. It's time to power up.

Notes

1. Dan Randall (deceased) was a leading industry advocate of digital color management. He played predominant roles in Datacolor and Konica-Minolta.
2. The "Big Ol' Department Store" noted herein was a significant retailer with a large variety of owned brands that were designed, developed, and sourced globally.
3. The $100 figure was appropriate when this article was written in 2007. As noted in last month's "The Cost of Color," that figure has gone up.

Articles from The Second C: Series

- Hoover, K. The Second C: Color with a Purpose. *AATCC Review*. **2022,** *22* (1), 36-39.
- Hoover, K. The Second C: From Inspiration to Replication. *AATCC Review*, **2022,** *22* (2), 28-32.
- Hoover, K. The Second C: Lab Dips—The First Circle of Hell (Part 1). *AATCC Review*, **2022,** *22* (3), 26-30.
- Hoover, K. The Second C: Lab Dips—The First Circle of Hell (Part 2). *AATCC Review*, **2022,** *22* (4), 32-36.
- Hoover, K. The Second C: Leaving Limbo. *AATCC Review*, **2022,** *22* (5), 34-39.
- Hoover, K. The Second C: The Sixth Circle of Hell—Heresy. *AATCC Review*, **2022,** *22* (6), 34-39.
- Hoover, K. The Second C: The Sixth Circle of Hell—Heresy, Part 2. *AATCC Review*, **2023,** *23* (1), 26-33.
- Hoover, K.; Merritt, R. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 1. *AATCC Review*, **2023,** *23* (2), 22-28.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 2. *AATCC Review*, **2023,** *23* (3), 22-28.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 3. *AATCC Review*, **2023,** *23* (4), 26-31.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 4. *AATCC Review*, **2023,** *23* (5), 34-39.
- Hoover, K. The Second C: The Cost of Color AATCC Review, **2023**, *23* (6), 34-43.

Keith Hoover, President of Black Swan Textiles, implements manufacturing-centric digital processes for color and fabric development. He has implemented digital color management programs for Ralph Lauren, Target, Lands' End, JCPenney, and Under Armour, ultimately leading to a process that eliminated lab dips altogether. At Under Armour, Hoover championed the UA Lighthouse, driving digitalization and advanced manufacturing processes to explore local-for-local sourcing. He has worked hands-on in mills worldwide and is a frequent AATCC presenter.