THE SECOND C: GOING TO THE LOO Part 3: Chromalucense & the Golden Eye

By Keith Hoover

"A joyous light thus beamed at me suddenly out of a dark age…."

—Johann Wolfgang von Goethe
"German colorist, poet, novelist, courtier, and scientist"

"Light, more light!" *said the dying Goethe.*
(the *dyeing* Goethe, would have said—**"Salt, more salt!"**)

In retail, color is everything. It not only defines the product but creates a first impression of the selling space to the customer. That is why color exploration is a key part of the design process—it enables a designer to attach something tangible to what is in the "mind's eye."

However, when it comes to finding those perfect colors, designers face the same limitations that their great grandparents faced—color standard reference sets with too few choices or a reliance on "found objects" (clippings of fabrics obtained from Heaven knows where). In an age of AI and smart phones, designers are stuck with tin cans and string technology for finding the right colors.

OLD-FASHIONED COLOR STANDARDS

When you think of a color standard, probably the first thing that comes to mind is a swatch of colored fabric (an LCT, or "Little Chippy Thing" in technical parlance). Even though color management in the apparel industry has adopted digital technology for dyeing fabric—Kubelka-Munk, CIEL*a*b*, DE_{CMC}, and the rest—the outcome is still an analog physical swatch (whether conventional or "engineered").[1]

Dyeing fabric to meet a typical production color difference tolerance of 1.00 DE_{CMC} requires dyestuff and process control because of the many variables in the dyeing process along with the inherently unlevel nature of most fabrics. The legacy color standards providers must meet even tighter tolerances (usually 0.50 DE_{CMC}). It can be argued that such a tolerance is tighter than their process capability, defined as the average DE_{CMC} plus three times the Standard Deviation of all production runs (see a discussion of Process Score in "The Second C: The Ninth Sphere of Paradise— Primum Mobile, Part 1," *AATCC Review*, March/April 2023).

Color standard providers usually control shade quality by scrapping samples that measure > 1.00 DE_{CMC}, possibly selling them as "color tools" for designers to make palette cards or some such rot. Additionally, they take steps to expedite the dyeing process to meet high demand and low-quality output (also known as doing stupid faster). And they raise prices.

All in all, the fashion industry's propensity to rely on swatches for color has been frustrating, counter-creative, and costly (see "The Second C: The Cost of Color," *AATCC Review*, November/December 2023).

Figure 1. White light illuminating blue fabric. Illustration generated by newarc.ai.

Figure 2. Blue light illuminating white fabric. Illustration generated by newarc.ai.

Figure 3. Blue swatch illuminated by white light in a viewing cabinet. Illustration generated by newarc.ai.

Figure 4. Blue light illuminating a white swatch in a viewing cabinet. Illustration generated by newarc.ai.

RETHINKING THE LIGHT AND OBJECT

In its most basic form, a color standard represents the interplay between light and an object. And, when pondering light and an object, we typically think of some version of a white light illuminating a colored fabric as shown in Figure 1. By selecting a standardized light source (specified by a given spectral power distribution and lux level), we can see the precise appearance of a color on that fabric.

But what if we flip the whole thing on its head? What if we select a white fabric and project a precisely colored light at a given lux level onto it (see Figure 2)? Wouldn't we perceive the same color whether a white light illuminates a blue swatch or a blue light illuminates a white swatch?

Indeed, we would. Assuming standard viewing conditions, the X, Y, and Z coordinates of both samples would be equal. However, there is more in play with color perception than just the color coordinates of two samples.

Let's move our example of equivalent colors from the setting in Figures 1 and 2 into standard viewing conditions (Figures 3 and 4). We immediately see how the color of the area surrounding each sample impacts our perception. The concept "simultaneous contrast" describes extreme examples of how the color of the area surrounding a sample affects our perception of it (see Figure 5). That is why a particular shade of neutral gray (N7 in the civilized world) is specified to minimize the effect of the surround.

So, although we can apply color to an object with light, there is more to it than just colored lightbulbs. But why does that matter (unless you're trying to recreate the Standard Observer experiment)?

Because the days of limited physical color reference sets and "found objects" as color specifications are over.

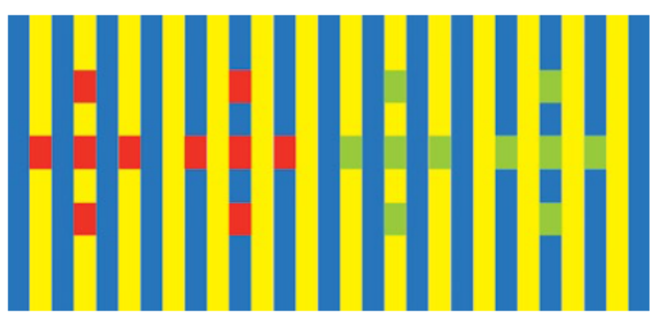

Figure 5. An example of simultaneous contrast.

CHROMALUCENSE—A NEW WAY TO EXPLORE COLOR

OK, so precisely applying dye to white fabric is hard. Is applying precisely colored light any easier? And how in the heck would you do it?

Three things are required in a "chromalucent" system—that is, a system that uses colored light as a vehicle to impart color to a white object. [2]

- A tunable light source with a large color gamut
- A controlled viewing environment with a neutral surround and all Standard Illuminants
- Software to explore and identify desired colors

Wide Gamut, Tunable Light Source

Many have tinkered around with onscreen color for nearly 30 years. Display technology has advanced from CRT, to LCD, LED, OLED, miniLED, microOLED, to QD-LED. But even with those improvements, no one has overcome the fact that a self-luminous monitor is a glorified lightbulb that presents color differently than a physical swatch. So, conventional display technology fails to meet this criterion.

There have been advances in multi-channel, tunable spectrum LED systems, most notably to produce various versions of white light in viewing cabinets. The spectral power distribution of various Standard Illuminants can be uploaded into the system and reproduced with variable (or tunable) output from the various LED channels (see Figure 6). As an analogy, think of a reflectance curve that can be reproduced from dyeing primaries. This tunability provides the ability to incorporate an almost limitless number of illuminants in a viewing cabinet that was heretofore limited to a half dozen lightbulb slots.

LED sources can be engineered to create colors other than white. Plus, the number of channels employed in the design determines the volume and the shape of the color gamut. LEDPanel, from Thouslight is an example of this technology (see Figure 7). Not only is its gamut larger than conventional display technology, but it is also significantly larger than the gamut of color models such as Munsell, NCS, and DIN as shown in Figure 8.

So, LEDPanel technology meets the first criterion of a chromalucent system.

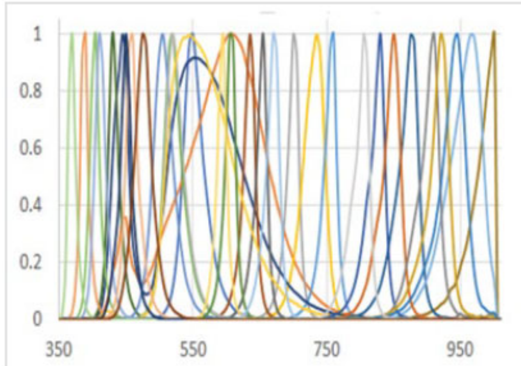

Figure 6. Channels in a multi-channel, tunable spectrum LED system. The output of each channel can be controlled to modify the color of the light emitted.

Figure 7. LEDPanel from Thouslight.

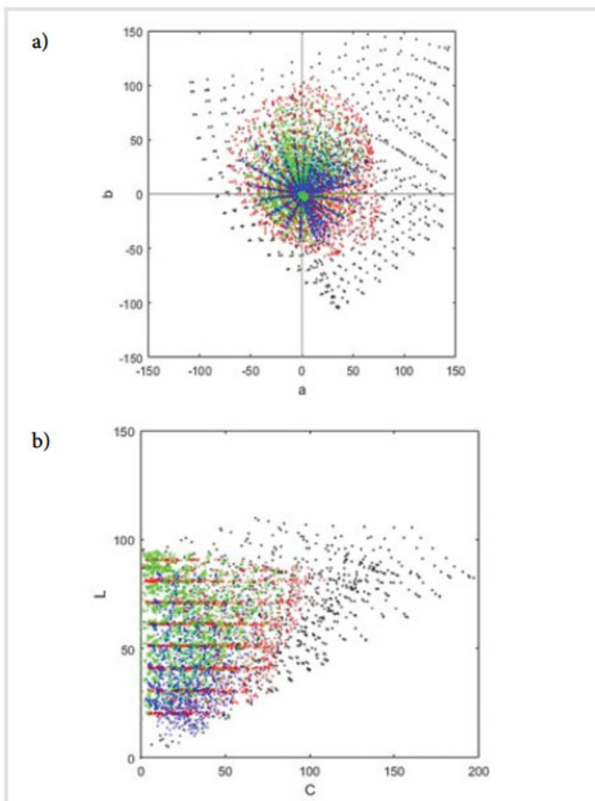

*Figure 8. The color gamut of LEDPanels is illustrated in these plots. Munsell (yellow), DIN (cyan), and NCS (green) samples are plotted in CIELAB a) a*b* and b) L*C*ab planes, respectively. The black dots are the display LUT data points.*

Figure 9. LEDView viewing cabinet, utilizing multi-channel, tunable spectrum LEDs instead of conventional bulbs.

Controlled Viewing Environment

Or a lightbox—the thing you look at lab dips in (or used to, if you've been reading this column). However, as mentioned previously, it should incorporate multi-channel, tunable spectrum LEDs instead of silly old lightbulbs for illumination. One such example of the current technology in viewing booths is LEDView by Thouslight, shown in Figure 9, which meets the second criteria of a chromalucent system.

Color Exploration Software

Software is needed to choose colors. There are many versions out there, but if you are an Adobe Creative Suite user, then you are used to using a color picker. I am no fan of the color picker—in fact, I think there is a special place in Hell for its inventor because it demonstrates a fundamental misunderstanding of color…but I digress. A better model for choosing color uses CIEL*a*b* and CIEL*C*h as coordinates to navigate color space.

When viewing and comparing chromatic colors (colors that can easily be categorized by primary and secondary colors), we tend to recognize variations in hue (the "h" in CIEL*C*h)—specifically, the primary or secondary color that falls on either side of the selected shade on the color wheel.

Next, we notice the brightness or dullness of a color (also known to people who like long words as chromaticity, or the "C*" in CIEL*C*h). A color's chromaticity changes by moving directly across the color wheel (towards the color's complement)—duller as you move towards the center and brighter as you move away from the center. Although red and green are complementary colors, you can't "see" green in a dull red or red in a dull green. But you can discern bright greens and reds from dull greens and reds—especially when their hues are constant.

When viewing achromatic colors (neutrals, greys, browns, etc.), CIEL*a*b* descriptors make sense since they describe differences in red, green, yellow, and blue. Hue and chromaticity don't really apply when viewing achromatic colors whereas slight differences in red, green, yellow, and blue are more discernable.

Regardless of how bright or dull a color is, its lightness or darkness (the "L*" in both CIEL*a*b* and CIEL*C*h) is readily apparent.

ColorWay is a program created by Thouslight to select color. As shown in Figure 10, the target color is in the middle with variations shown in the surrounding grid. The user can see and adjust variations of that color in either CIEL*C*h or CIEL*a*b*. Think of being able to immediately visualize comments you have made on labdips (such as "too red and dull"). You can navigate through the ColorWay grid in real-time to see what actually happens when you change the hue and chromaticity, previewing what the dyer must do to improve the match.

PUTTING PIECES TOGETHER

We have identified the pieces, now let's see how they fit together.

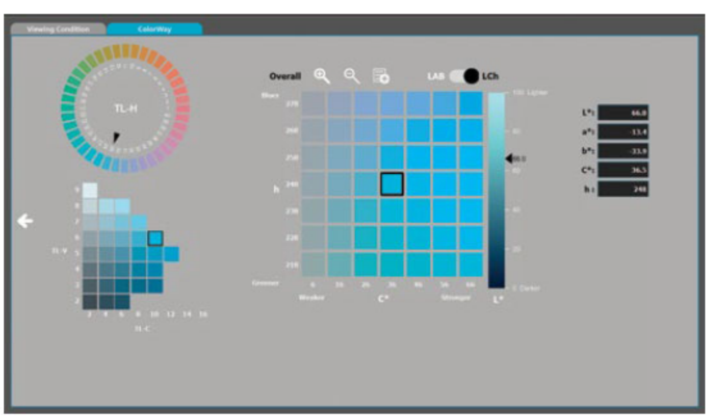

Figure 10. The ColorWay color selection software.

LEDSimulator

Figure 11 shows LEDSimulator, [3] a system enabling a designer to explore and navigate continuously through the entire dyeable color space using precisely colored light applied to any white substrate. LEDSimulator incorporates a LEDView viewing cabinet with LEDPanels (attached to the back of the cabinet) projecting specific colors defined in ColorWay onto a white fabric viewable through an aperture on the back wall of the LEDView cabinet.

Figure 11. The LEDSimulator system. Top: Back view showing LEDPanels and a colored fabric swatch. Bottom view: Viewing area with 1) the aperture showing the chromalucent colored fabric and a chromalucent colored fabric swatch and 2) a laptop with ColorWay software.

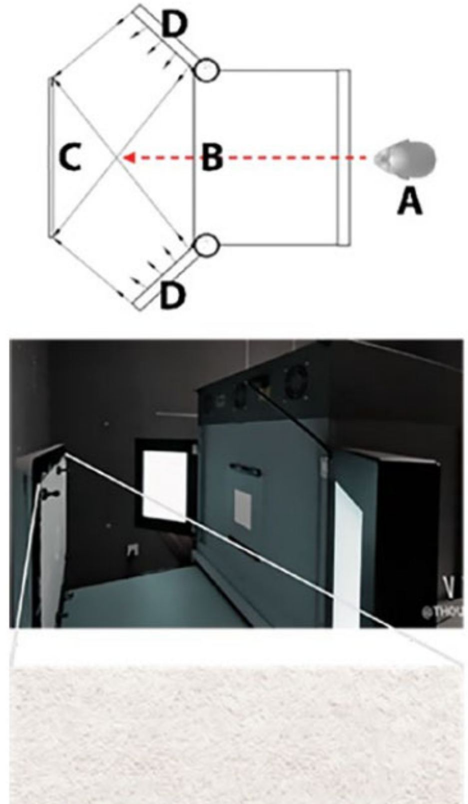

Figure 12. LEDSimulator system configuration

Figure 12 illustrates the LEDSimulator system configuration. The top image shows a bird's eye view of the system. From right to left, the designer (A) looks through a window in the back of the LEDView cabinet (B) to view a fabric sample (C) illuminated by two LEDPanels at a 45°: 0° geometry (D). The middle image is a photograph of the back of the system projecting white light onto a fabric sample. The bottom image is a close-up of the fabric sample. Figure 13 shows the same sequence of images with cyan light created in ColorWay illuminating the fabric sample.

LEDsimulator Use-Cases

Let's look at Figure 13 again, this time with the color selection process in mind. Designers create new colors in ColorWay by entering RGB or L*a*b* values, importing a QTX file from many popular color reference collections, or just making stuff up as they go (the true freedom of exploration). Once a color is created in ColorWay, a signal from the software is sent to the two LEDPanels (D) that illuminate the desired material with the precise color (C). The designer (A) can then see the new color on a specific fabric by viewing it through an aperture in the back wall of LEDView (B), which incorporates standardized light sources to create optimal viewing conditions.

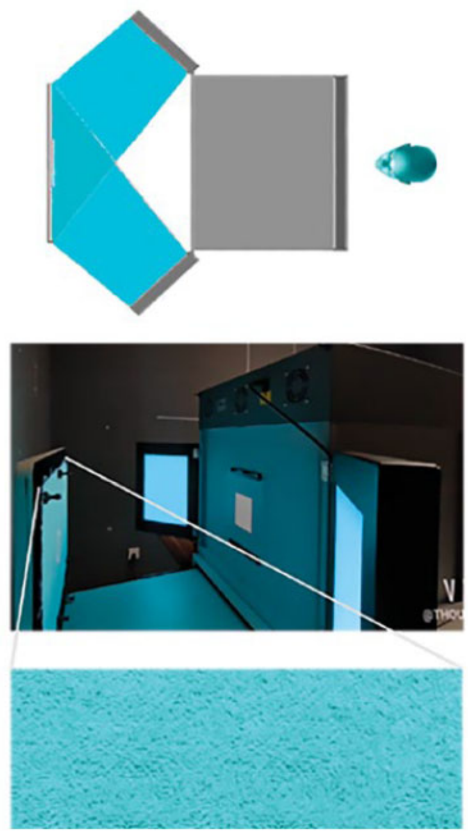

Figure 13. LEDSimulator producing a cyan shade

Controlling the Variables

Each color created in ColorWay and viewed in LEDSimulator factors in the Illuminant selected in LEDView. For example, "Blue Hoozywhatzit" looks different in D65 than in Incandescent (boy, does it ever). And, since colors are created in LEDSimulator, the effect of the specified light on color is immediately perceived. This avoids the problem of selecting great colors in weird places and then being surprised when they are seen in the store.

Designers can also swap out fabrics in LEDSimulator to understand "Total Appearance," that is, the impact of texture on color appearance. This is a valuable feature when considering fabrics with considerable texture. Designers can make slight adjustments to a color on specific fabrics ("substrate specific standards") to optimize for Total Appearance. Heretofore, this has been a trial-and-error process between the designer and the dyer, each trying to read the other's mind (no, we won't talk about presuming facts not in evidence, Perry Mason).

From L*a*b* to Spectral Data

ColorWay uses proprietary "Close Point" IP to convert the single illuminant L*a*b* coordinates specified in ColorWay into spectral data. This method was derived from an analysis of 100,000 reflectance curves incorporating various materials, colorants, and performance properties.

Spectral data for each newly invented color can then be stored in a database or sent directly to mills for dyeing. So, literally in minutes, new colors can be selected, viewed on specific fabrics, defined as feasible spectral data, and communicated to mills for matching.

All of that without MOQ's for color standard purchases, out-of-stock notices, or confiscatory invoices from standards suppliers. This is what "digital color" was meant to be.

Hey, What About the Problem with the Standard Observer…

In the first two "Going to the LOO" (Light, Object, Observer) installments (*AATCC Review*, September/October and November/December 2024), I spelled out the apples and oranges problem presented by using the CIE Standard Observer color matching functions (CMFs) when modeling colors to be visualized in technology like LEDSimulator. In essence, we are pitting the way that the Standard Observer "sees" color against the way that individual designers perceive color (theoretical CMFs vs measured CMFs). These CMFs are not interchangeable.

Furthermore, I proposed an "acid test" for evaluating chromalucent technology like LEDSimulator—the visual match quality must be comparable to viewing two pieces of the same physical non-textured color swatch side-by-side.

The simplest way to achieve this would be to substitute the designer's personal CMFs for the Standard Observer when calculating color coordinates like L*a*b*. But that is impractical from a logistical point of view and destroys the standardization on which digital color communication relies. We can't be faced with the prospect of countless individual CMFs when calculating color difference.

A better way to pass the acid test is to build an individual correction matrix for each designer using LEDSimulator. The LEDSimulator matrix shifts the system to behave as if the designer's individual CMFs were in use. However, the integrity of the underlying color coordinates calculated using the Standard Observer is protected. It is roughly similar to (although not the same as) instrument profiling.

THE COLORIST AS A GOLDEN EYE

As we enter the age of digital color exploration and specification, I propose the "Golden Eye" concept. A Golden Eye is a master colorist responsible for the brand's color aesthetic point of view from individual colors to color palettes. Not only are Golden Eyes good at selecting the right colors (accuracy), but they are consistent in the way they define color, time after time (repeatability). They can apply method to madness.

Establishing Golden Eyes in the design studio accomplishes two key goals. First, it acknowledges the preeminent importance of color as a product attribute.

- Color attracts the customer to the product
- Price gets the product to the dressing room (some might argue for handfeel here, as well)
- Fit moves the product to the check-out counter
- Quality brings the customer back to the store

Second, it recognizes and rewards the skill and talent of a competent colorist. Just as a CFO is responsible for bean-counting, a Golden Eye is responsible for color-driven sales.

IT'S LONELY AT THE TOP

Gone are the days of color selection by committee. Choosing the right color is a skill, dare I say it, a gift. It's not a hobby. So, colors should be selected by one person—the right person, not some chucklehead product life management (PLM) person who "really likes" color.

In the last installment, I mentioned that everyone's CMFs are different—some radically so. However, LEDSimulator's correction matrix is built to meet the requirements of one user at a time—most often, the Golden Eye. Several matrices can be created to support several users, but since only one matrix can be applied at a time, two users won't see the "same color" when viewing LEDSimulator color simulations together.

THE FUTURE LOOKS BRIGHT

Over the past three years, we have examined color, from inspiration to replication, hopefully giving business context to the theories that deliver results.

Frankly, a lot of this technology has been around for years. I could make the case that my mentor, Ben Bell, was way more innovative tuning the oscilloscopes on a gargantuan COMiC spectrophotometer in 1960 than most textile colorists looking at lab dips in old-school lightboxes are today. The technology he implemented at Burlington Industries had a huge impact on quality, time, and cost—three key proformance indicators(KPIs) valued by manufacturers.

Instruments have gotten smaller and more precise. Software has become easier to use. All of which means that we can do the same things faster today than Ben could do 64 years ago. But, in essence, we're still doing the same things. And in some cases, we have reverted to bad practices (as in all-visual evaluation). Imagine the CFO demanding to witness every sales transaction because he doesn't trust ApplePay.

LEDSimulator harnesses new technology to solve an age-old problem—color exploration. Check it out. Consider what life would be like if choosing color were as easy as drawing a flat in Illustrator—or paying for something by scanning your phone.

Notes

[1] From a color replication point of view, spectral data—not the physical swatch—is the true color standard. However, replication can only take place once a standard has been selected. Color, like all aesthetic properties, is a psycho-physical attribute

[2] Yes, I made up that word. Kinda cool-sounding, though, don't you think?

[3] For more information, visit **https://www.thouslite.com/product_detail/169.html**

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.

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, Part 1. *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.
- Hoover, K. The Second C: The Truth About Color Revisited. *AATCC Review*, **2024**, *24* (1), 26-33.
- Hoover, K. The Second C: A Higher Class of Problem. *AATCC Review*, **2024**, *24* (2), 24-28.
- Hoover, K. The Second C: A Higher Class of Problem, Part 2. *AATCC Review*, **2024**, *24* (3), 32-36.
- Hoover, K. The Second C: Two World Views, *AATCC Review*, **2024**, *24* (4), 32-39.
- Hoover, K. The Second C: Going To the LOO, Part 1: Dips, Diapers, and the Standard Observer, *AATCC Review*, **2024**, *24* (5), 40-43.
- Hoover, K. The Second C: Going To the LOO, Part 2: Oedipus Meets the Standard Observer, *AATCC Review*, **2024**, *24* (6), 24-28.

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