A New Test Method Based on CIELAB Colorimetry for Evaluating the Permanence of Pictorial Images

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Introduction:

Efforts to publish a new light-fastness test method and subsequent specification document pertaining to digital print media has been proceeding on the basis of adaptation of earlier chromogenic materials standards (ANSI IT9.9 and more recently IS0 18909). The existing standards have exclusively cited the use of densitometry with Status A and Status M densitometric filter sets. From a historical perspective, Status A and M sets were tuned to the typical spectral characteristics of chromogenic dyes. Because broad parity existed within the industry in terms of the spectral properties of the various dye sets, in almost all cases the materials to be tested produced visually neutral gray step wedges when equal R, G, and B density values were measured. However, in the current digital era of highly diverse colorant sets, even within a single technology class such as inkjet materials, we can no longer rely on reasonable consistency of neutral gray patch fabrication based on specified densitometric aim points. Additionally, the historical ANSI and ISO test methods only tracked losses of density from a single initial aim point of 1.0, although more starting aim points were allowed (WIR has for many years employed two aimpoints: 1.0 and 0.60).[1] This seemed reasonable only because the traditional dye-based chromogenic systems lost density uniformly across their full tonal scale, resulting in a more or less parallel shift (light fade) or linear slope change (thermal aging) over the majority of the densitometric curve. Today, this type of performance cannot be assumed. Catalytic fading, non-uniform printed dot dispersions, three, four, six, seven, eight (or more) ink colorant sets with different blending levels, and varied black component placement by GCR techniques means that the full tonal scale performance cannot be reliably inferred from measurements of just one or two initial density points. For these reasons, full tonal scale behavior should be evaluated.

Another factor to consider is that while densitometry has long been the process control data of choice for the photo finishing and printing industries, the digital imaging market is now rapidly embracing a color-managed workflow. Consumers at the amateur level know or care little about RGB or CMYK data in image files, and even less about CIELAB or densitometry, but the serious amateur and professional photographic market is clearly becoming more informed and anxious to adopt a fully color-managed workflow. A color-managed workflow is based on colorimetric not densitometric characterization of monitors, printers, scanners, and to some extent digital cameras. Fluency in the meaning and image editing of RGB, CMYK, and LAB data is increasing. Software to characterize devices and build and edit color profiles has advanced tremendously in the last few years. With regard to image quality metrics it now makes more sense to produce samples for pictorial image quality studies using colorimetric methods rather than densitometric methods.

The problem with densitometry:

Tables I and II demonstrate a significant problem with densitometry in this new imaging era, namely, the inconsistent prediction of visually neutral gray patches. Neutral patch densitometric readings for six different printer/ink/media combinations are listed. Also included are measurements for two chromogenic color papers. The inkjet systems were profiled with Gretag Macbeth Profilemaker 4.1/Spectroscan software and hardware, and then neutral patches with L = 51 and L = 36 aim points and a*b*= 0 were printed. These neutral tones correspond to 0.71 and 1.05 Visual density levels (i.e., the "Visual" filter setting on a densitometer). RGB density values of the same neutral patch aim points were also derived from IT8.7/2 reflection scanner targets for the chromogenic color prints. As can be seen in Table I and Table II, equivalent Status A density values corresponded well with visually neutral colors that approached $\Delta a*b* = 0.0$ for the chromogenic papers only. Equivalent RGB density values would not have produced visually neutral patches for any of the inkjet materials. It can also be seen that the measured LAB values of the printed samples were remarkably close to the chosen colorimetric aim points for all inkjet systems, albeit with slightly worse results for the Epson 2000P. The 2000P had poorer results due more than likely to the nonlinearity of its "no color adjust" driver setting and metameric performance of the colorant set. Nevertheless, the ΔE between the printed samples and the aim point LAB value of the patches was less than 2.0 in all printed samples except the L=51 level on the 2000P. Its 3.2 ΔE result is still in reasonably good agreement. Thus, the ICC profiling software worked well on a diverse group of inkjet

Table I										
Printer	Ink	Paper	Aim points (Lab and Status A)			Actual Measured values Status A (Red, Green, Blue, Visual)				
			L*,a*,b*	ΔE	O.D.	ΔE	Red	Green	Blue	Visual
Lexmark Z53	Lx	Kodak Ultima Glossy	51, 0, 0	0.0	0.71	1.8	0.62	0.66	0.69	0.69
Epson 890	Ep	Ep Prem Glossy Photo				0.7	0.69	0.74	0.80	0.71
HP 7150	HP	HP Prem Plus Photo G				0.8	0.68	0.72	0.77	0.72
Epson C82	Ep	Matte Heavyweight				1.0	0.61	0.69	0.73	0.70
Epson C82	Ep	Xerox Prem Brt white				1.6	0.62	0.70	0.73	0.70
Epson 2000P	Ep	Ep Prem Luster Photo				3.2	0.58	0.76	0.90	0.71
IT8.7/2 target	N.A.	Fujicolor Paper				0.8	0.73	0.74	0.74	0.72
Q-60 target	N.A.	Ektacolor Paper				2.6	0.73	0.74	0.70*	0.71
Lexmark Z53	Lx	Kodak Ultima Glossy	36, 0, 0	0.0	1.05	1.9	0.94	0.97	1.02	1.03
Epson 890	Ep	Ep Prem Glossy Photo				0.6	1.02	1.08	1.17	1.06
HP 7150	HP	HP Prem Plus Photo G				0.8	0.97	1.03	1.12	1.03
Epson C82	Ep	Matte Heavyweight				1.9	0.94	1.01	1.02	1.03
Epson C82	Ep	Xerox Prem Brt white				1.2	0.96	1.02	1.04	1.02
Epson 2000P	Ep	Ep Prem Luster Photo				1.7	0.90	1.08	1.29	1.04
IT8.7/2 target	N.A.	Fujicolor Paper				0.9	1.06	1.06	1.07	1.04
Q-60 target	N.A.	Ektacolor Paper				2.7	1.08	1.08	1.04*	1.05
* patches appeared visually slightly blue (b* ~ -2.5) which accounted for larger ΔE and lower blue channel density value										

Table II				
Printer	Ink	Paper	Density Range between R,G,B	
			L = 51	L = 36
Lexmark Z53	Lx	Kodak Ultima Glossy	0.07	0.08
Epson 890	Ep	Ep Prem Glossy Photo	0.11	0.15
HP 7150	HP	HP Prem Plus Photo G	0.09	0.15
Epson C82	Ep	Matte Heavyweight	0.12	0.08
Epson C82	Ep	Xerox Prem Brt white	0.11	0.08
Epson 2000P	Ep	Ep Prem Luster Photo	0.32	0.39
IT8.7/2 target	N.A.	Fujicolor Paper	0.01	0.01
Q-60 target	N.A.	Ektacolor Paper	0.04*	0.04*
* Probably 0.01 to 0.02 had neutral patch not been slightly blue.				

printing systems that included media from glossy photo to plain paper. The density range (difference between the three channels) is listed in Table II. For the 2000P, the density range exceeded 0.30! A densitometrically calibrated neutral would appear visually to be excessively cyan-blue, and with a cyan-rich/yellow-reduced mixture the neutral gray patches could perform differently in a light fading experiment than if they were calibrated to appear more visually neutral.

The problem with single (or double) aim point analysis:

As we work more and more with non-traditional photographic media (e.g., inkjet), tracking one or two aim points densitometrically may lead to results that do not correlate well with actual
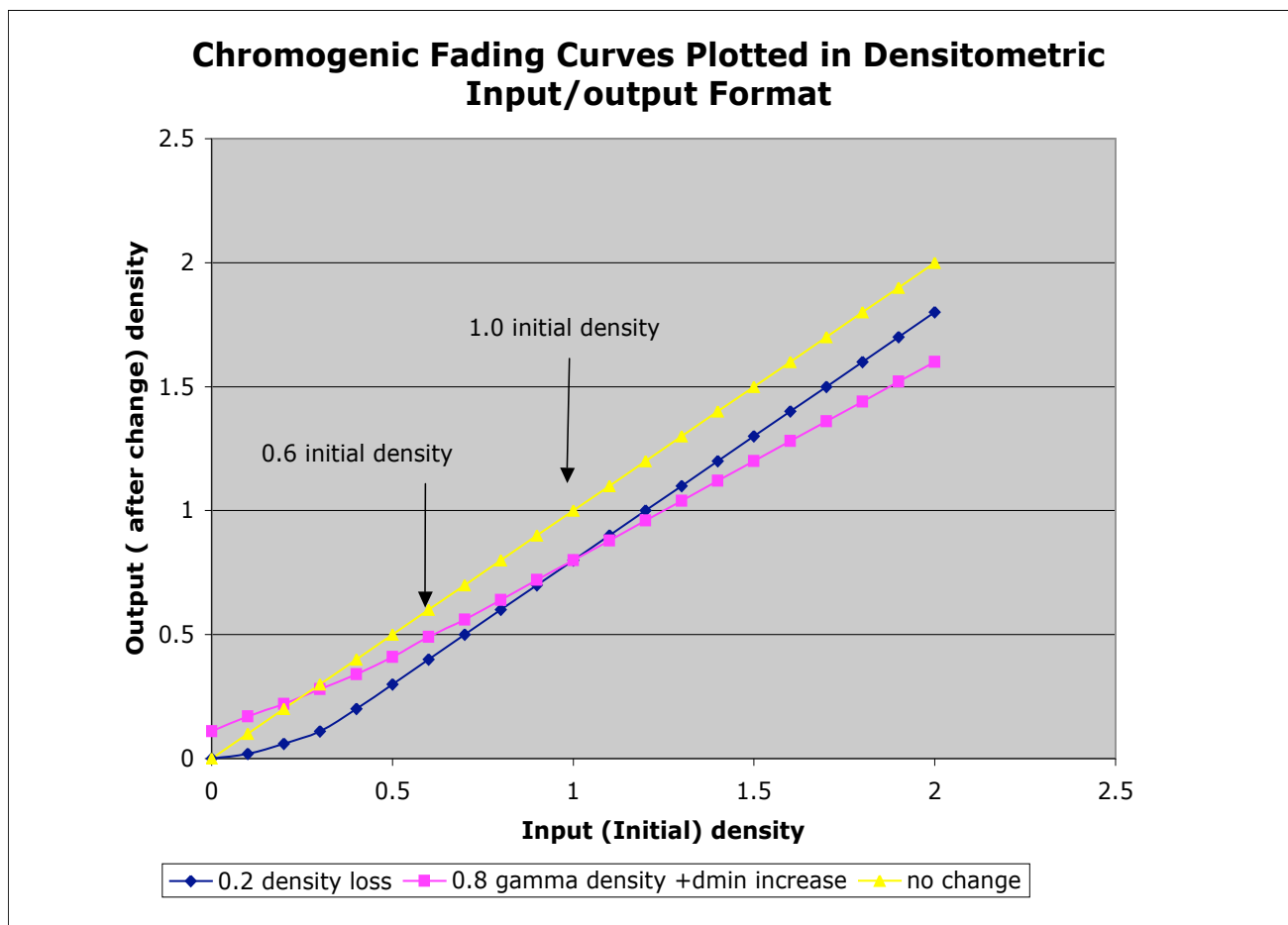

Figure 1. Traditional densitometric curve changes . The "0.2 density loss" curve represents a typical light fade reaction and the "0.8 gamma density + dmin increase" curve is a typical thermal reaction.

pictorial image changes. As illustrated in Figure 1, monitoring one or two densitometric aim points was a reasonable approach in the past only because chromogenic color systems fade with predictable tonal response. Since the typical curve change is fairly linear, tracking one or two density points adequately accounted for the potential overall curve response (except at the highlight end of the light fade curve).[2] Thus the test data could be assumed to correlate reasonably with changes that would be observed in a pictorial image. Figure 2 shows the same curve changes plotted in CIELAB Lightness units rather than densitometric units, (i.e., visual density values have been converted to L values). The curves no longer plot in a completely linear fashion although they are well behaved and can still be characterized by following one or two selected aim points. Figure 2 also reveals that tonal curves plotted in L units can give greater insight on changes in pictorial image appearance. For example, the parallel density drop now plots with increased slope in the mid tone and shadow portion of the scale when expressed in L value units. It indicates that light induced fading of a chromogenic print will not only yield a lighter print with bleached out highlights, but also one that is increasing in visual contrast for mid tones and shadows. Figure 3 illustrates the kind of nonlinear lightness behavior one may obtain with modern digital print systems such as inkjet. Local distortions caused by catalytic fading, dot overlap, light versus dark ink cartridge transitions in 6-ink formulas, etc. is likely to result in a non uniform tonal scale. We conclude that a superior experimental method requires tracking the response of the full tonal curve, and that failing to do so may lead to misranked test results that don't correlate with end-user experience.
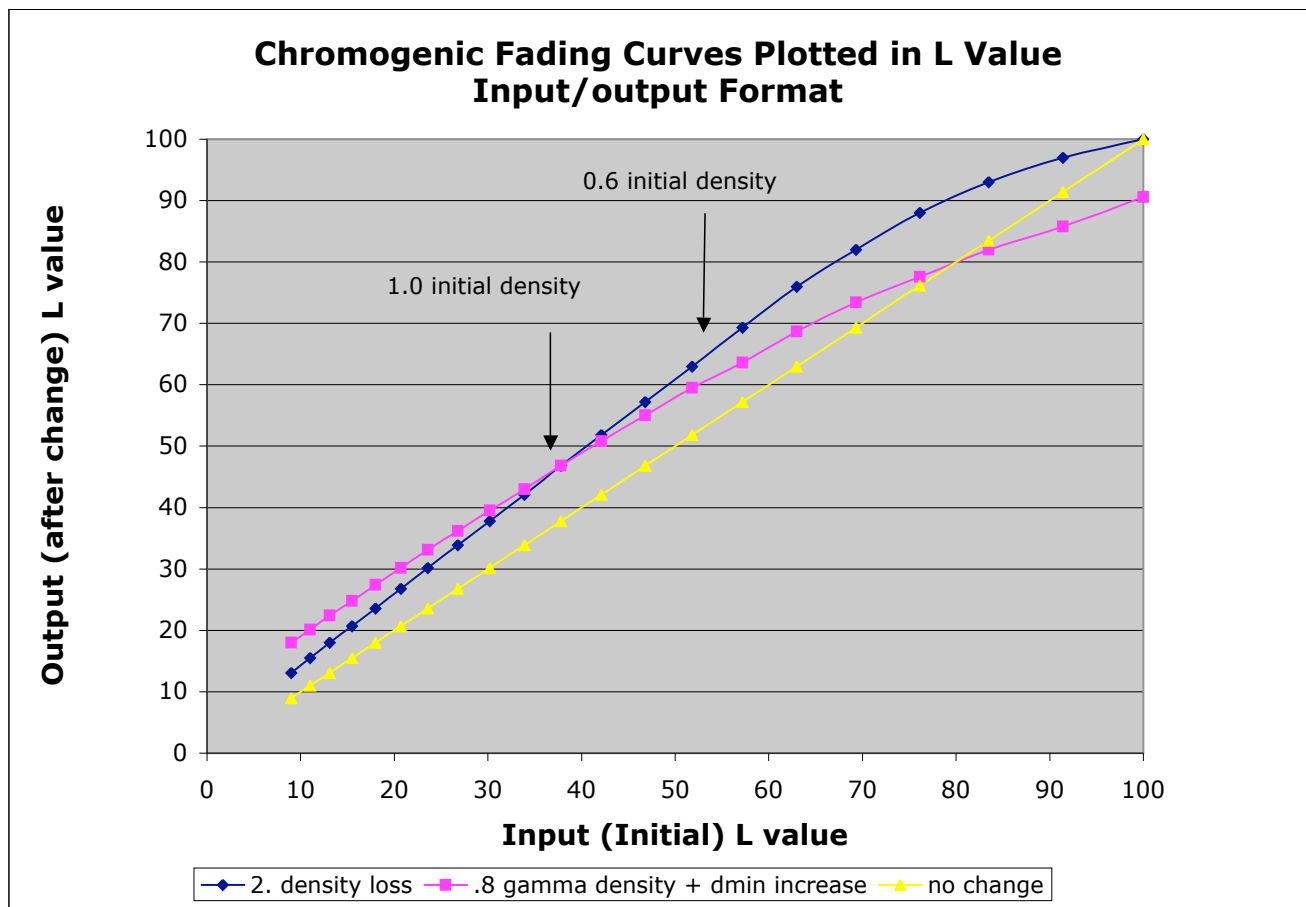

Figure 2. Same data as in Figure 1 except plotted in L value units. Curves become slightly bowed, but tracking the amount of fade at two points is still a viable way to characterize the total response for traditional chromogenic color materials.
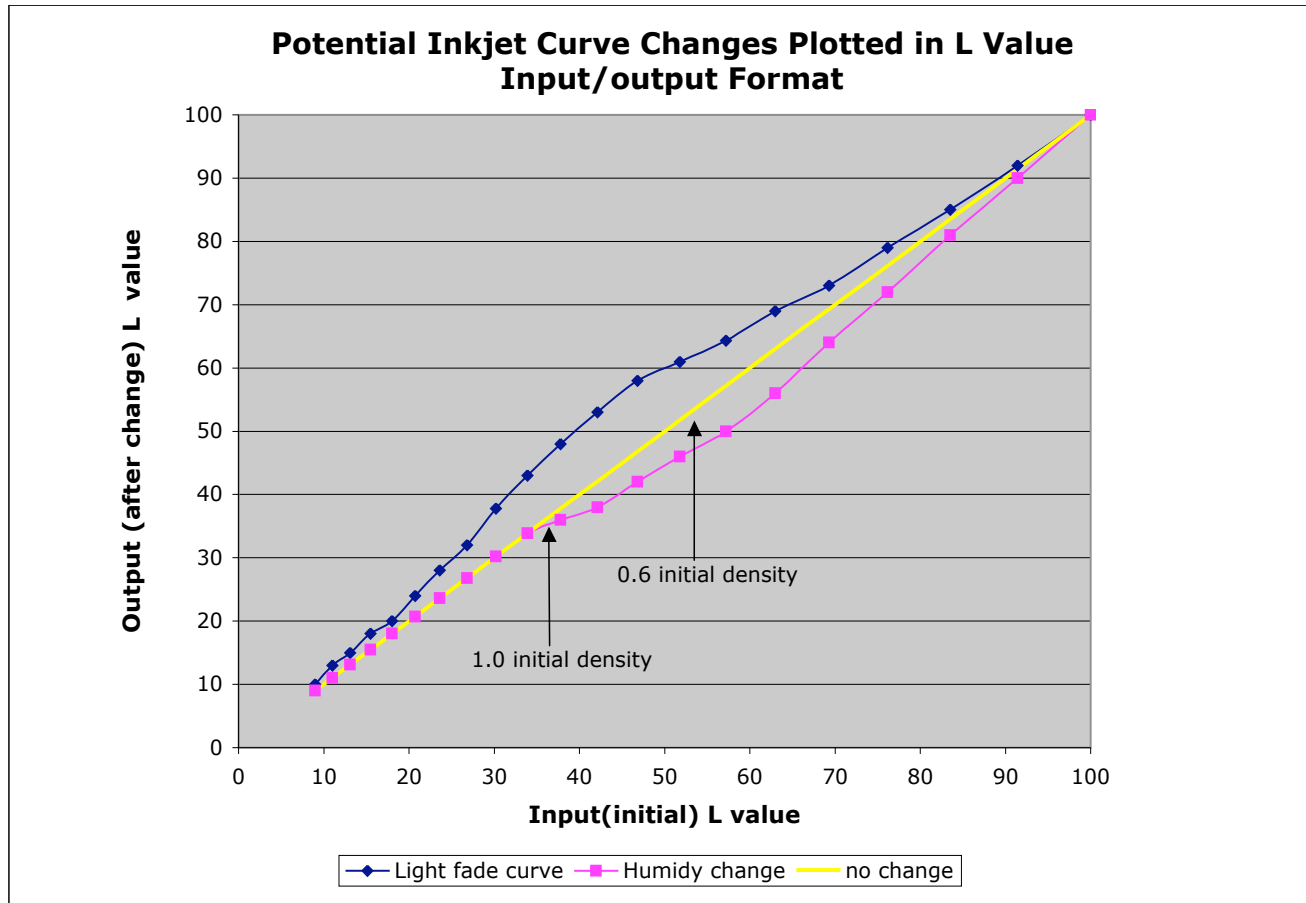
Figure 3. Unpredictable L scale behavior if only a limited number of points are plotted. Local distortions caused by catalytic fading, dot overlap, light versus dark ink cartridge transitions in 6-ink formulas, etc. are likely to cause irregular curve shapes as illustrated here.

Issues with Colorimetry:

The ISO WG5/TG-3 task group has had numerous discussions and one or more round-robin experiments in recent years comparing the pros and cons of densitometry versus colorimetry. Some of the original arguments were related to accuracy of the equipment. A recent round-robin test suggests that this is no longer a serious issue. The print profiling spectrophotometers on the market today which use 0/45° instrument geometry agree quite well. We routinely use spectrophotometers even when generating Status A densitometric data with highly repeatable results. They provide the spectral data from which colorimetric and densitometric values can easily be calculated. Another concern has been with the use of ΔE. Concern has been raised that ΔE says something about magnitude but not direction of change. However, to generate ΔE one must collect the LAB data, and thus direction of change results are available if one desires to examine these trends. Nevertheless, while we see validity in ΔE for specific applications, our recommendation is ***not*** to use ΔE as the figure of merit in light fading tests related to pictorial image applications.

      From WIR's ongoing research towards the implementation of a fully colorimetric approach to image permanence, we have concluded that the more significant issue with colorimetry is not so much a problem with CIELAB or any difficulty in measuring colorimetric data. Rather it stems from the color difference models that are routinely used to express changes in appearance. ΔE and

its variants (ΔE94, ΔECMC, etc.) seem reasonable to use when an analysis is confined to a simple quantification of perceptible differences between two closely but not perfectly matching patches. Quantifying the closeness of match between a repainted car fender and the rest of the car is a good example. ΔE is also a reasonable figure of merit for quantifying process repeatability, say for example, to study short term printer drift. It may at times roughly correlate to certain visual changes that are observed when comparing two photographs. However, poor correlation is so easy to demonstrate that we question if the conventional color difference models are a justifiable approach to ranking perceived image quality. For example, a color digital image can be fully desaturated to become a black and white image. In a side-by-side comparison of the two images, ΔE is enormous, but both images are perceived to have reasonable image quality because the lightness relationships have been preserved and hues become undetermined but not "wrong" in the black and white image. Or consider reading this text printed in bright yellow on white paper. The measured ΔE between the white paper and yellow type can easily meet or exceed the ΔE between the black type and the white paper, but the black text is far easier to read. What then is the specific nature of a color difference and how is it applicable to pictorial images? Again, our ability to read the text is a function of the lightness component that set up the visual image contrast. The ΔL between the yellow type and white paper is much less than the ΔL between the black type and the white paper.

To summarize, the concept of combining lightness, chroma, and hue differences to form a single figure of merit (ΔE) for difference between two colors is satisfactory when we are examining only two near-neighbor, slightly dissimilar patches. However, people see photographs not by isolating one or two colors at a time but by mentally processing contextual relationships between colors where the changes in lightness, hue, and saturation contribute independently to the recognition of spatial patterns in the image. These contextual relationships cannot be properly weighted by assigning roughly comparable units of change for lightness (L), red-greenness (a*), and blue-yellowness (b*) as do the current color difference models. In fact, the lightness component is critical to the spatial formation of the image so an appropriate colorimetric test method for image quality must evaluate the lightness component separately from the a*b* component.

Additionally, the current color difference models appear to be flawed with respect to chroma in the context of perceived image quality. The ΔE chroma equation utilizes the Δa* and Δb* values between two colors regardless of their initial chroma values. In a natural scene or an image reproduction of that scene, low chroma colors, especially neutral and near neutral colors plus white areas are used (often subconsciously) by the observer to adapt to the scene and discount the illuminant. Thus, shifts in the a* and b* values of these areas in a photographic reproduction are much more serious than comparable shifts of a* and b* in highly saturated colors because they become incompatible with the white balance established by the print illuminating conditions (often using paper white as a key adaptation point). This fact is why digital image processing algorithms used to enhance or reduce color saturation of an image apply a percentage increase or decrease term to the numbers rather than an addition or subtraction term. Adobe Photoshop®, for example, uses the CIELAB colorspace as the underlying processing architecture and multiplies the a* and the b* terms of each pixel value by a fixed percentage to increase or reduce chroma. Thus, a strictly neutral value where a* and b* equal zero, when multiplied by 10%, for example, remain unchanged whereas a color with 50 units of a* and 70 units b* would become 55 a* and 77b* by that operation (thus increasing chroma while maintaining hue). If an addition or subtraction scheme were used, the neutral and near neutral colors would take on chroma and hence establish new and distinct hues in regions where they shouldn't exist, thus ruining the color balance in the image.

Considerations for a colorimetric target design:

For many desktop printers on the market today, the printer driver attempts to emulate the color space of a typical sRGB monitor so that the consumer sees printed colors that come closer to the ones viewed on the monitor. Thus, the selection of a "pure" digital color, for example, R=255, G = 0, and B = 255 to produce magenta, actually prints more than magenta ink in order to emulate the magenta color displayed with that digital value on a typical monitor. In other cases, printers may be true CMYK devices, allowing "pure" ink colors to be printed by driving cyan, magenta, yellow, and black ink output uniquely from C, Y, M, and K data channels. In yet other instances, some RGB printers let the C, M, and Y inks to be printed in isolation because a driver setting can be found that assigns yellow ink to the B channel, magenta ink to the G channel, and cyan ink to the R channel (e.g., R=0, G = 255, B = 255 prints pure cyan ink). Thus, in the current densitometric test method-ology, some test targets may be prepared that have patches containing only single colorants, while other test targets may always contain some mixture of more than one colorant. Additionally, differ-ent printer/ink/media systems have different maximum density and color gamut limits. For these rea-sons, although matching densitometric aim points is simple, the goal of having every printer print an identically colored test target is impossible. Even when carefully adjusted to precise densitometric aim points and those aim points are achieved, the test targets will vary in actual color from printing system to printing system. It is not difficult to devise a target with precise densitometric aim points achievable by a high percentage of printing systems even as we concede that actual color matching is not met. One needs merely to select maximum densities that aren't too high. The historical use of a 1.0 density patch has been essentially within range of virtually all printing devices that claim to have some measure of "photographic quality." To summarize, since chroma value of the test patches is not specified or measured by the densitometric criteria in the current light-fading test methodology, the production of test targets has never been a significant problem.

In a colorimetric test methodology, we have a much greater ability to achieve test targets that are matched colorimetrically. However, an across-the-board match on all printers is still not achievable due to the widely varying color gamuts of the various systems on the market. Selecting colorimetric aim points that have high chroma are unobtainable on low gamut systems while set-ting low gamut aim points to encompass a wide range of printers and materials does not adequately test the performance of printers with high gamut capability. Thus, like densitometry, we can set a colorimetric aim point but unlike densitometry, we must reconcile how to handle low-gamut sys-tems that are not capable of meeting the desired aim points. After careful consideration, it appears that a test target should not be constrained to low gamut colors. Rather, a reasonably colorful target that is representative of moderate to high gamut system performance should be chosen, and sys-tems that cannot meet the aim point must be allowed to fall short in a way that does not destroy the integrity of the test method and also in a way that is easy to accommodate. The practical approach to this problem is to use a color management method that maps unobtainable saturated colors to less saturated color within gamut without altering hue and lightness to a degree that damages the test criteria. Then, the test's tolerance for the final printed values is achieved by adopting a test criteria set based on relative lightness compared to paper white and also contrast differences rather than specific initial L value aim points. By following these design objectives, target preparation should be a relatively straight-forward task facilitated by standard color management methods rather than a highly laborious task based on trial and error matching. Figures 4a and 4b show a preliminary target design. Table III lists values for the target. The colors were derived from chromogenic color print systems and IT8 colorimetric values. They could easily be adjusted to conform more closely to typi-

Figure 4a. LAB test target. Color rendering intent will proportionally compress the scale into smaller system gamut.

Figure 4a. LAB test target. The color patches have been arranged to permit efficient automatic sampling by commercially available spectrophotometers.

cal inkjet output, for example. It should be noted that the chosen hue and saturation values in each non- neutral row follow visual hues and saturation levels of the chromogenic color print systems with the exception of the skin tones which have been based on the Macbeth Colorchecker® values for light and dark skin tones. CIELAB lines of constant hue are well known to have perceptual discrepancies, although a target design using constant hue in CIELAB units would probably suffice.

The routine determination of a contrast specification in conjunction with the proper test target need not be difficult to implement. By using relative L values and tracking contrast (gamma between two L value points) rather than specifying absolute L values as initial patch values, the test algorithm can accommodate high and low gamut systems by printing the LAB target through an ICC profile with perceptual or relative rendering intent. Hand tuning of each patch on every printed test target should not be necessary, although at times some patches may need to be adjusted manually. Manual adjustment would not be entirely by trial and error since the LAB value of a patch can be checked and adjusted numerically in appropriate image editing software such as Adobe Photoshop®.

With this type of colorimetric approach, a highlight criterion can also be introduced by, for example, setting a specific contrast limit that is different in the highlight region than in the mid- tones and shadows. Our research indicates that critical information in highlights (e.g., the embroidered pattern of a wedding dress) is preserved as long as some minimal contrast remains in the image high-

Table III - CIELAB values relative to normalized paper white (100, 0, 0)								
White	Yellow	Magenta	Cyan	Red	Green	Blue	Skin	Neutral
100, 0, 0	95, 0, 46	95, 9, -5	95, -6, -5	95. 6, 5	95, -7, 6	95, 1, -5	95, 4, 6	95. 0. 0
	90, 6, 78	90, 17, -11	90, -15, -11	90, 12, 9	90, -13, 12	90, 2, -11	90, 9, 11	90, 0, 0
	80, 16, 98	80, 35, -21	80, -26, -20	80, 25, 17	80, -24, 23	80, 5, -21	80, 15, 18	80, 0, 0
		70, 51, -34	70, -24, -29	70, 38, 25	70, -33, 29	70, 9, -31	70, 16, 19	70, 0, 0
		60, 66, -37	60, -40, -35	60, 51, 35	60, -42, 31	60, 12, -39	60, 16, 18	60, 0, 0
		50, 76, -37	50, -41, -36	50, 60, 43	50, -48, 32	50, 16, -48	50, 16, 18	50, 0, 0
				40, 61, 44	40, -50, 33	40, 18, -55	40, 15, 16	40, 0, 0
						30, 19, -57	30, 15, 16	30, 0, 0
						20, 32, -66	20, 15, 16	20, 0, 0
							10, 7, 8	10, 0, 0
								0, 0, 0

lights. A good contrast and lightness criteria set should also work well to track decreases in lightness (i.e., print getting darker) caused by a humidity response, as well as irregular slopes forming in the full tonal scale due to problems like catalytic fading or image degradation caused by ozone. Thus, a single target design can serve for most types of image permanence tests. The water resistance test may be an exception and require a specific test target design.

A Colorimetric Criteria Set (preliminary):

Based on the work completed to date and also by studying how the current WIR criteria set translates into a colorimetric space, a preliminary specification for a new colorimetric criteria set is expressed as follows:

The change in the colorimetric target design (see figure 4a and b)) shall not exceed:

1).   Color change = 33% x C_i or $8\Delta a^*b^*$, whichever is greater. C_i is the initial chroma value (the square root of the sum of Δa^* squared and Δb^* squared).

2).   a) Highlight contrast change = ±60%, based on gamma of the tonal curve segment, S_1 where $S_1 = \Delta L$ between Paper white, L_1, and target patches with L values = L_1- 5 (+1.5,-0) units. Segments S_1, S_2, S_3, etc., are illustrated in Figure 5.
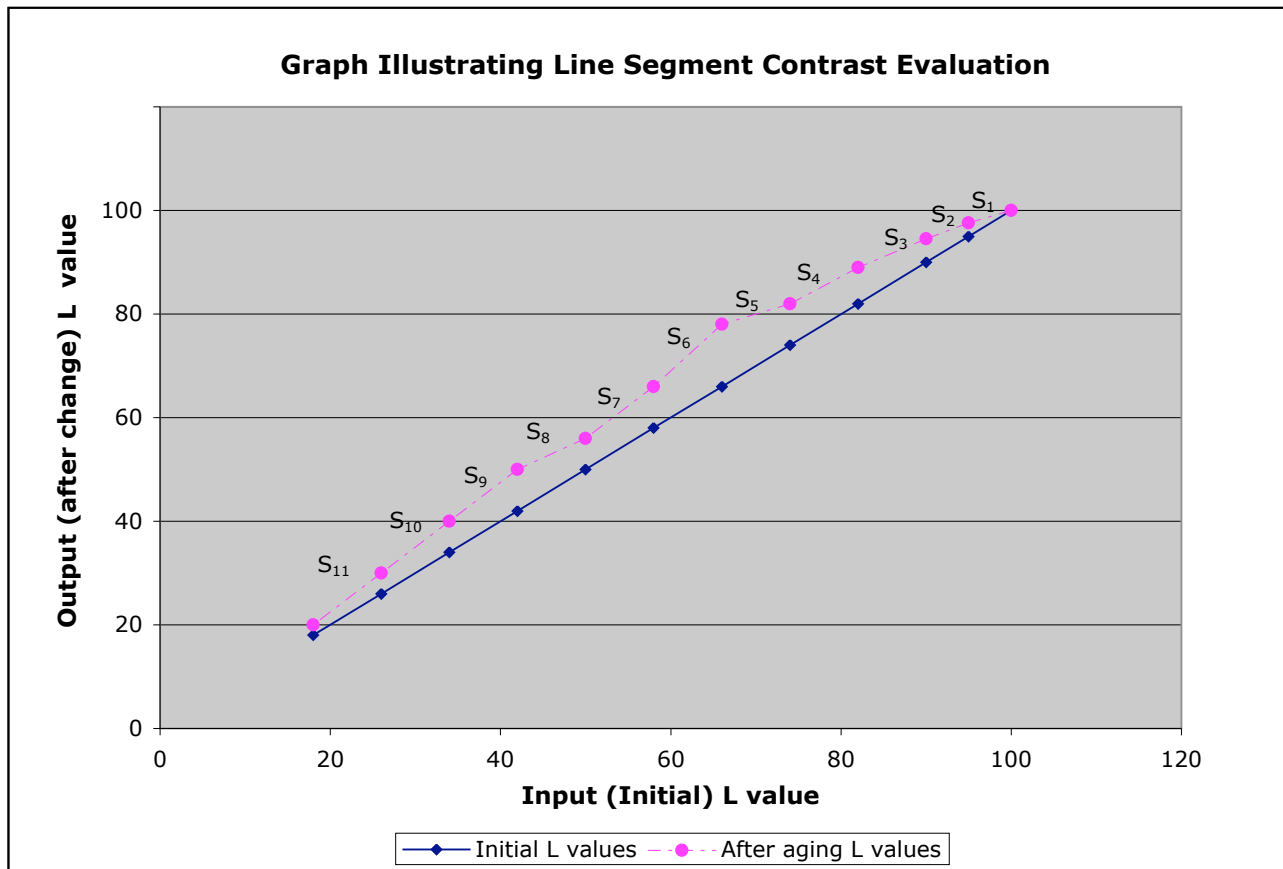
Figure 5. The difference in relative L values between target patches of the same hue establishes line segments S_1, S_2, S_3, S_4, etc. These line segments are used to compute contrast changes.

b) Highlight contrast change = ± 40%, based on gamma of curve segment, S_2, where S_2 = $L_1 - L_2$ = 9 (+2,-0) units.

c) Mid tone and Shadow contrast change = ±20%, based on the gamma of all curve segments S_3 and greater that also meet the additional requirement that their ΔL intervals equal 7, (+3,-0) units. The additional requirement would be part of the target preparation specification. It allows small gamut systems to compress the L scale and perhaps clip the lowest patch values that comprise the data for segments S_{10} and S_{11}.

3).   Paper White change = 12Δa*b* or 5L, whichever is greater.

Item 1) constrains colors with chroma less than 24 to 8Δa*b* units while allowing high chroma (pure colors like cyan, magenta, yellow, red, green, blue) greater latitude. Yellow hues for example, often have C_i ~ 60 which allows 20 Δa*b*. Skin tones typically have chroma values from 18 to 24. Item 2) is the contrast function that will catch unusual tonal breaks in an image caused by catalytic fading etc. while allowing linear drops comparable to the WIR densitometric criterion of 20% density loss at 1.0 and 0.60. Although traditional chromogenic materials would be likely to fail on the highlight tolerances, inkjet and certain other digital print technologies may perform well with respect to loss of highlight detail since these systems lay down dot patterns of full-concentration inks rather than continuous analog dispersions of color in the highlight patches. One possibility with the collected contrast data is that it can be used to report an image longevity range. For example, a sample failing on the highlight component of the criteria set can be given a year rating to reach highlight loss while its performance on the remaining criteria can be used to set an upper limit to the display life rating. This information is useful to professional photographers, especially wedding and portrait markets where high key portraits are common (e.g., white wedding dress in front of a white backdrop). They can make an informed judgement when comparing systems since a reported range would reveal what product is more susceptible to highlight detail loss without under reporting its capability for non-highlight critical images. Item 3) is the counterpart to the WIR Dmin stain criteria. The attempt in this specification is to reconcile the visual impact between high chroma stains (e.g., strong yellow shift) versus low chroma stains that alter L more than Δa*b*.

Parametric study of the criteria set using psychophysical testing procedures:

The preliminary criteria set and test target design described in this paper comprises a first effort to specify a test method based on CIELAB colorimetry. As noted previously, the colorimetric criteria have been derived in part by examining how the existing WIR densitometric criteria set translates into colorimetric terms. The WIR criteria set was developed over many years by conducting focus group studies with light-faded and thermally-aged pictorial images. Before the advent of digital image editing, it was hard to augment a psychophysical study with simulations of endpoints because color balance and density changes that simulated actual light-induced curve changes were very difficult to produce in the traditional darkroom. Today a colorimetric approach and digital imaging control can generate samples with precise visual contrast and color balance shifts. Figure 6 illustrates a colorimetrically calculated color balance shift while lightness and contrast of the images is kept the same. Automated spectrophotometers and spreadsheet programing ensure that data collection and analyses are not difficult for either simulated aging samples or actual pictorial samples where target patches can be printed along side the image and aged under the same conditions (see

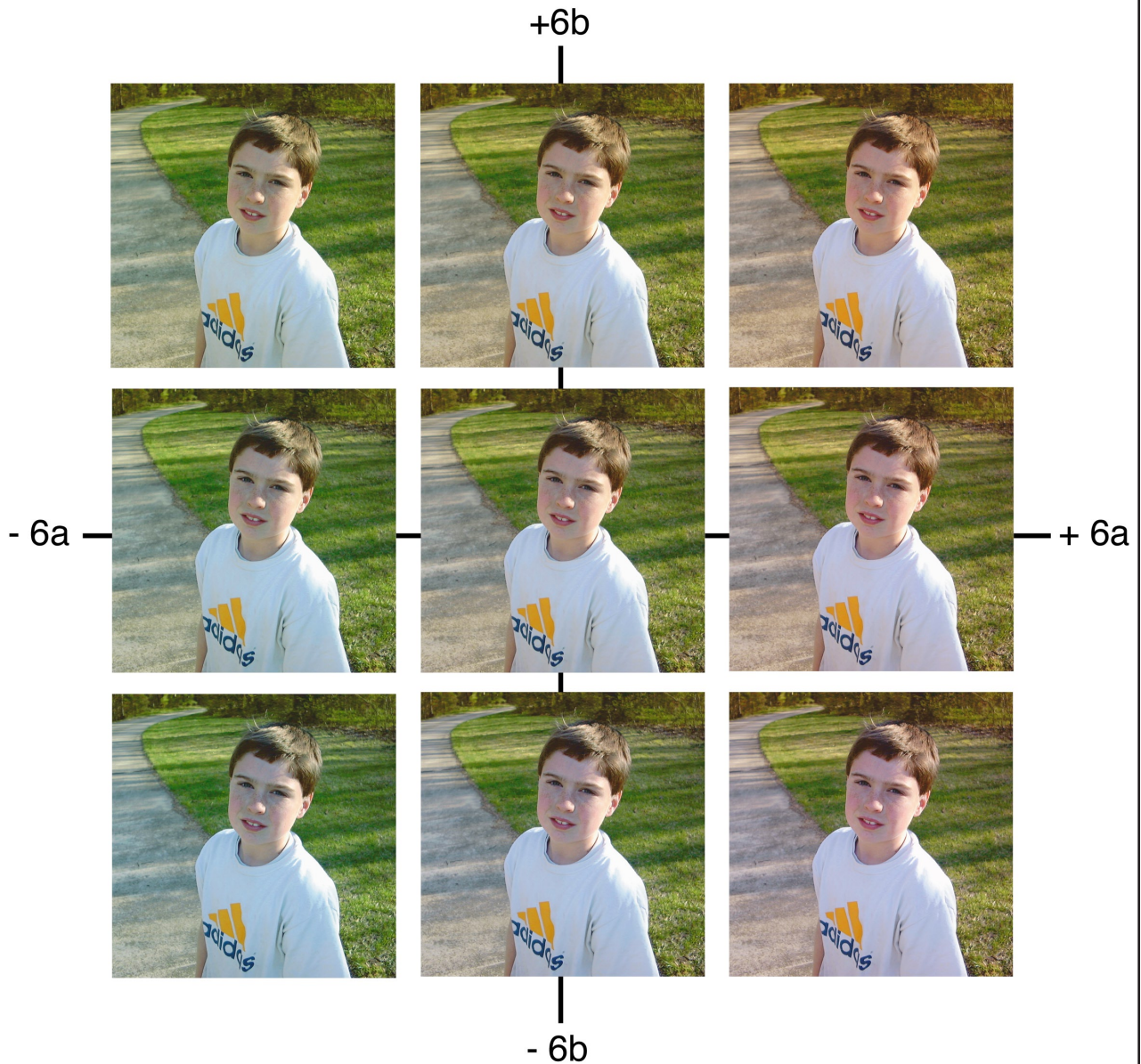*Note: Viewing on a calibrated sRGB computer monitor will display this PDF document with correct color.*

+6b

- 6a

+ 6a

- 6b

Figure 6. This matrix of images has been adjusted so that the a* and b* values are shifted between images in 6 unit increments for pixels with relative L values between 40 and 60. Matrices are extensible in finer increments and longer ranges for psychophysical testing purposes. An image in the center of a matrix need not be designated the "best image". An observer may choose his or her preferred color balance from any of the images in the matrix since the colorimetric relationship between images can be calculated. However, in Figure 6 the images in corners have both a* and b* values adjusted simultaneously so $\Delta a^*b^* = 8.5$ compared to the center image. Images to the immediate right, left, top, and bottom of center are moved only in the a* or b* direction so $\Delta a^*b^* = 6$. An 8.5 Δa^*b^* value is very close to the allowed color balance shifts in the current WIR densitometric criteria set for light-fastness. Changes of this magnitude are described by WIR as "noticeable" fading. The adjustments were done with tonal curves so that as areas of the image reach the ends of the tone scale (i.e., highlights and shadows) the magnitude of color shift diminishes to zero. Thus highlights and shadows are only very slightly affected while the main strength of the color shift occurs through the mid tones. The L value of each pixel remains unaffected so contrast is not changed in this example. Digital image editing can produce many subtle curve changes. Once a desired adjustment is made, it can be saved and applied automatically across a wide variety of pictorial images in order to test how different scenes respond to the same kind of colorimetric changes.
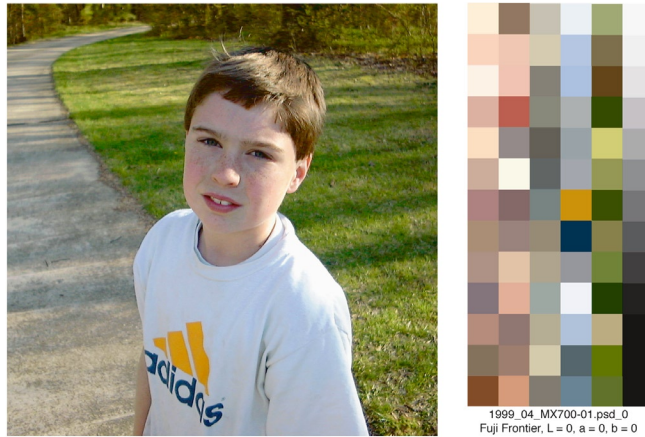
1999_04_MX700-01.psd_0
Fuji Frontier, L = 0, a = 0, b = 0

Figure 7. Sampled pixels from the image and other target patch data can be used to calculate the colorimetric change in aged or age simulated pictorial image samples.

Figure 7). Figure 8 shows the curve changes made in RGB color space to produce the image in the upper right corner of Figure 6. This image differs from the center image by +6a*, and +6b* units at corresponding relative L values between 40 and 60. As often occurs in an actual light fade test, the color shift has been tapered off as the lightness values approach highlights and shadow areas of the image. RGB rather than LAB editing space is required to make this type of adjustment but the changes are guided by the LAB information obtained from the PCS (profile connection space) data using color profiles for the destination print space. This method is routine color management in practice and does not require difficult or complex techniques.

Prints made on a Fuji Frontier digital minilab which vary in color balance in steps of 3a* and 3 b* units from -9 to + 9 differences about a centered reference image have been produced to demonstrate the colorimetric approach in the production of pictorial images that vary in selective amounts with respect to colorimetric endpoint criteria.

Conclusion:

Densitometric data remains very useful for process control and R&D applications. However, an image permanence test applicable to the wide variety of digital print technology on the market today must accommodate systems that do not produce visual neutrals using Status A or other densitometric filter sets. Additionally, the analysis of full tonal scale behavior is the only way to be certain that comparative results for different systems are correctly ranked. Given these facts, the current test methods that have been considered to date require further validation if they are to be used confidently with digital print technologies. In view of the amount of work that is involved in attempting to confirm the existing densitometric methods, it is appropriate to consider a fully colorimetric approach to image permanence testing. This new test method uses target preparation and analysis of visual change that are applicable not only to light stability and Arrhenius thermal aging tests, but also for humidity-fastness and gas-fading tests. In addition, this test method is applicable to both color and monochrome pictorial images.
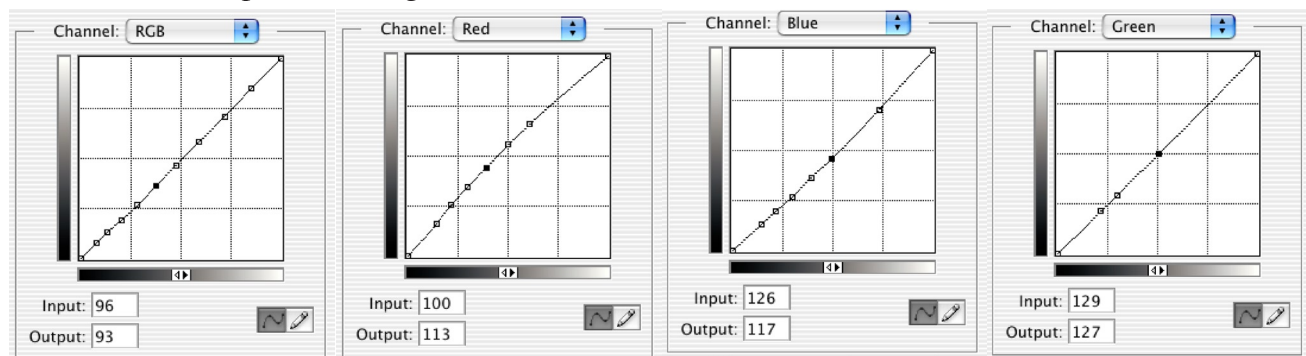

Figure 8. Composite, Red, Green, and Blue curves adjusted to render colorimetric aimpoint for pictorial image shift as shown in Figure 6, upper right corner image.

References

1) Henry Wilhelm, "How Long Will They Last? An Overview of the Light-Fading Stability of Inkjet Prints and Traditional Color Photographs," *Final Program and Advance Printing of Paper Summaries, IS&T's 12th International Symposium on Photofinishing Technology,* pp. 32–37, Orlando, Florida, February 20–21, 2002.

2) *ANSI IT9.9–1996 American National Standard for Imaging Materials – Stability of Color Photographic Images – Methods for Measuring*, American National Standards Institute, Inc. New York, NY, Table A.1 and A.2, page 22, 1996.