A COLORIMETRIC STUDY OF THE EFFECT OF SOME PRESS VARIABLES ON COLOR REPRODUCTION IN LITHOGRAPHIC OFFSET PRINTING

Ming-Shong Lan*, Peter Lin**, and Lawrence J. Bain**

ABSTRACT

Several factors affect the quality of printed colors in lithographic offset printing. From a process control point of view, the quality of the process color of print samples can be controlled by adjusting the ink key settings and dampener settings on each printing couple. In this work, we investigate the effect of these press control variables and the press speed on process color reproduction in lithographic offset printing. Since spectrophotometers and colorimeters have been widely used in the printing industry, we use a spectrophotometer to measure the color of printed samples, which is expressed in a CIELAB (L*, a*, b*) triplet. The printing tests were conducted by printing GATF newspaper test forms on a Goss Universal Offset Press. We also investigate the effect of press temperature on color variations during press transient at the start-up. In addition, we characterize the color variations of samples printed under the same printing conditions.

Introduction

Saleh's 1982 TAGA paper[1] includes a fairly complete list of variables that affect the appearance of the printed color reproduction. The list contains the variables in seven categories: graphic reproduction, plate, paper, water, ink, human, and printing presses. From a process control of point of view, however, the quality of the process color of print samples can only be controlled by adjusting the ink and dampening solution feedrates during press runs. Often, the effect of these adjustments relies on skillful press operators, and the longer press operators take to do this, the more production time and material are lost. An automatic control system with an on-line color sensory feedback will not only reduce waste, but also increase printing quality.

* The Science Center of Rockwell International Corp.
** Rockwell Graphic Systems of Rockwell International Corp.

To develop such a control system, it is important to understand how the quality of printed color is affected by the controllable and uncontrollable variables. Because of the stochastic nature of the process due to the uncontrollable variables such as the variations in print inks, paper, and press temperature, etc., it is also important to characterize the color variations of samples under the same press settings. Such characteristics in steady-state color variations can be used to specify achievable tolerance.

The controllable variables in color printing are ink feedrates, dampener feedrates, and press speed. In this study, we investigated the effect of dampener feedrates and press speed. Of several uncontrollable variables, we investigated the effect of the press temperature since it is a dominant one.

This paper will first report the study of steady-state color variations, then describe the study of the colorimetric effect of press variables on color reproduction.

Experimental Setup

In our printing experiments, a Universal Offset Press (UOP) was used to print GATF newspaper test forms on 35-pound uncoated newspaper. Cyan, magenta, and yellow of Flint ANPA open fountain inks were printed in sequence, i.e., cyan first, magenta next, yellow last. Meanwhile, Flint V2020 dampening solution, which has a conductivity of about 1800 micromhos and a pH value of about 10.8, was used. During printing runs, press temperatures at various locations were also measured by using thermocouples and an IR temperature sensor.

We obtained data from cold-start/pre-stable conditions as well as data showing the variations of CIELAB L*, a*, and b* values relative to various press speeds and dampener settings under normal running conditions. For some experiments such as cold start, ink keys on all three printing units were initially set to achieve gray balance on the gray bar. The detailed settings for various printing conditions will be mentioned when discussing the test results.

A spectrophotometer manufactured by Applied Color Systems was used to measure the print samples. It measures the reflectance of a sample at each wavelength of the visible spectrum and gives L*, a*, b* values as well as C* and h values, in which L* defines lightness, a* denotes the red/green value, b* shows the yellow/blue value, C* specifies chroma, and h denotes hue angle[2][3]. We use L*, a*, b* triplet to express a color in our work. In our study, the printed samples were measured on the gray bar of either one page or both pages of the GATF newspaper test forms.

Steady-State Color Variations

Measuring color at the same location on different samples printed under the same set of printing conditions may give slightly different L*, a*, b* values. The possible causes include: 1) normal printing variability producing somewhat different dot sizes; and 2) the sensor not being placed on precisely the same area of print each time. In order to get a feel for the measurement repeatability and its distribution, we printed 100 consecutive copies after a cold start. (It was assumed that at that time the press had become stable.)

The middle points of the gray bar on both pages of the test form were measured. Figure 1 (a), (b), and (c) plot L*, a* and b* values and their distributions of 100 copies measured on the right-hand page; while Figure 2 (a), (b), and (c) plot L*, a*, and b* values and their distributions of 100 copies measured on the left-hand page. Table 1 summarizes the ranges of L*, a*, and b* for these samples. A similar study of the steady-state distribution of optical density measurements was reported in [4].

Table 1

	Range
L* (R)	56 -> 59
L* (L)	64.5 -> 67
a* (R)	-5 -> -2.5
a* (L)	-4 -> -2
b* (R)	0.5 -> 4
b* (L)	3 -> 5.5

R: right-hand page; L: left-hand page

Meanwhile, 32 locations on the gray bars of two consecutive printed copies were measured to check measurement repeatability; the values of L*, a*, and b* of 32 measurements on both copies are plotted in Figure 3(a), (b) and (c), respectively.

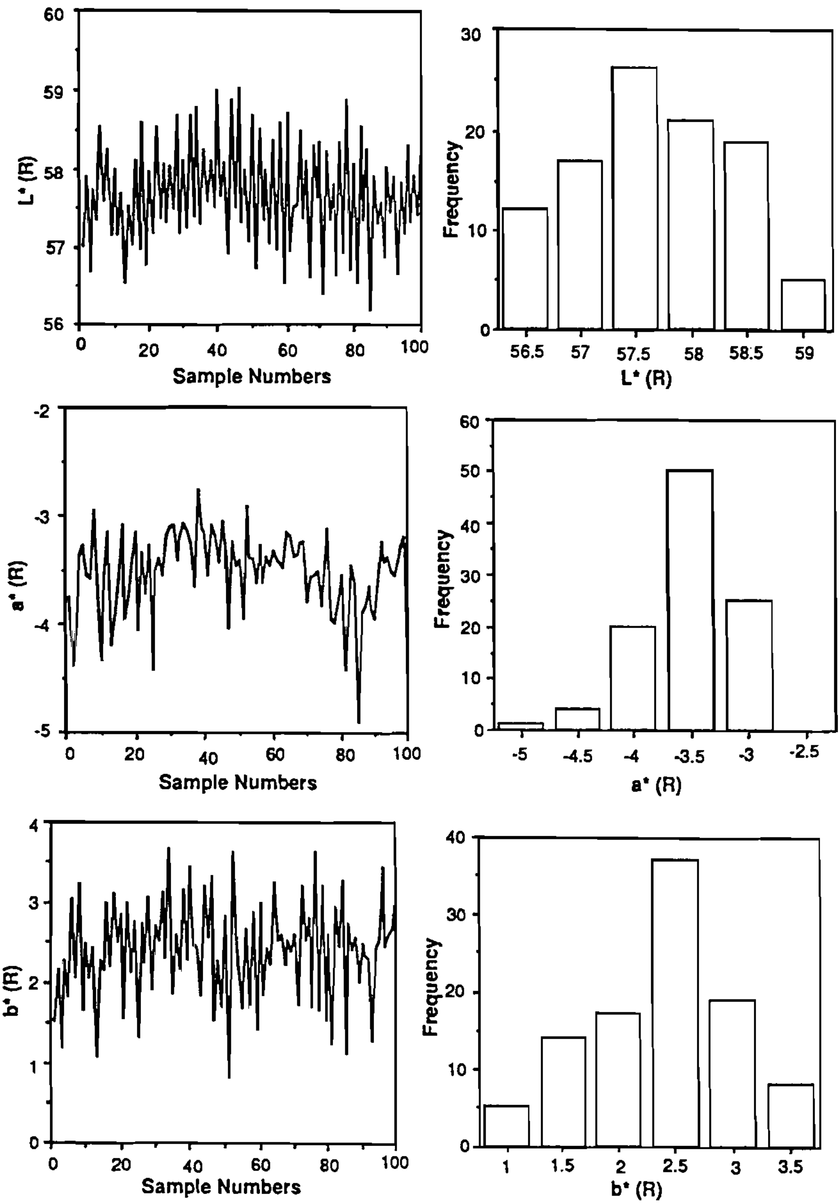

Figure 1 L*, a*, and b* values and their distributions of 100 consecutive printed copies measured on the right-hand page of the GATF test form.

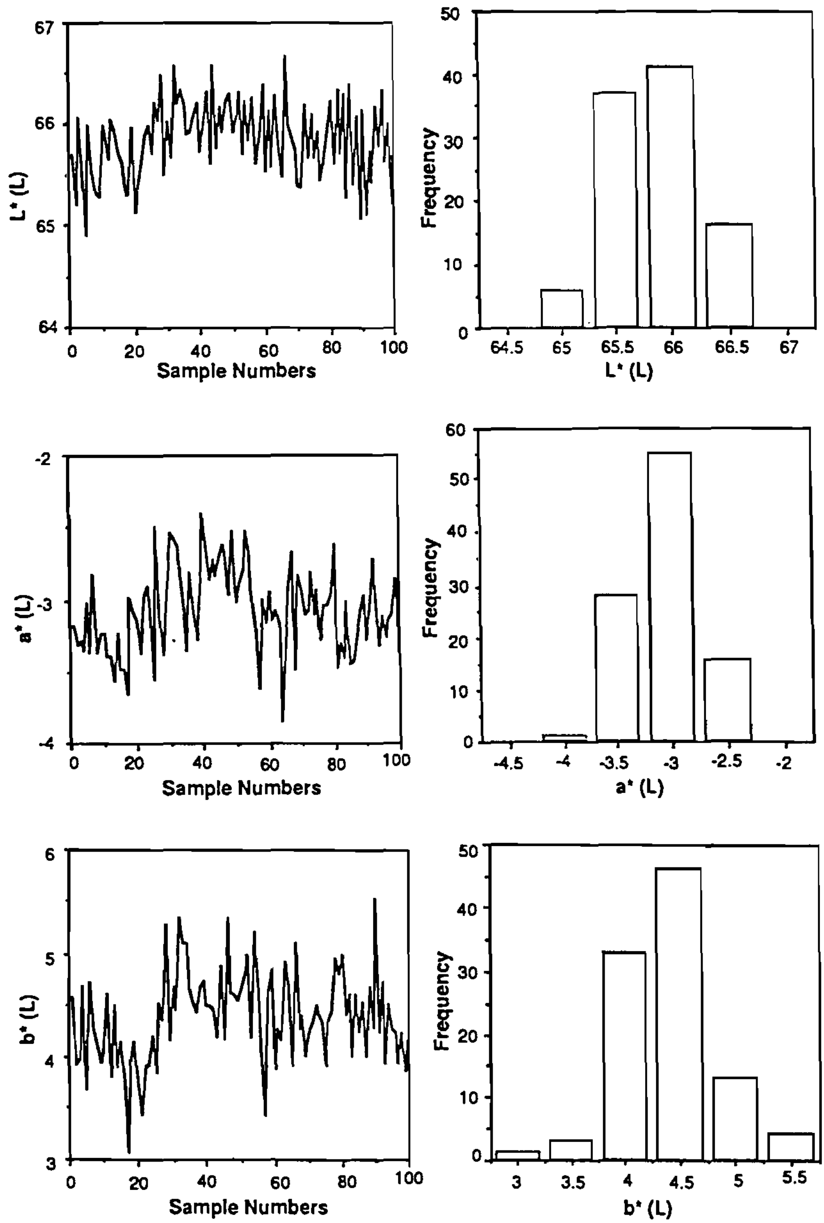

Figure 2 L*, a*, and b* values and their distributions of 100 consecutive printed copies measured on the left-hand page of the GATF test form.

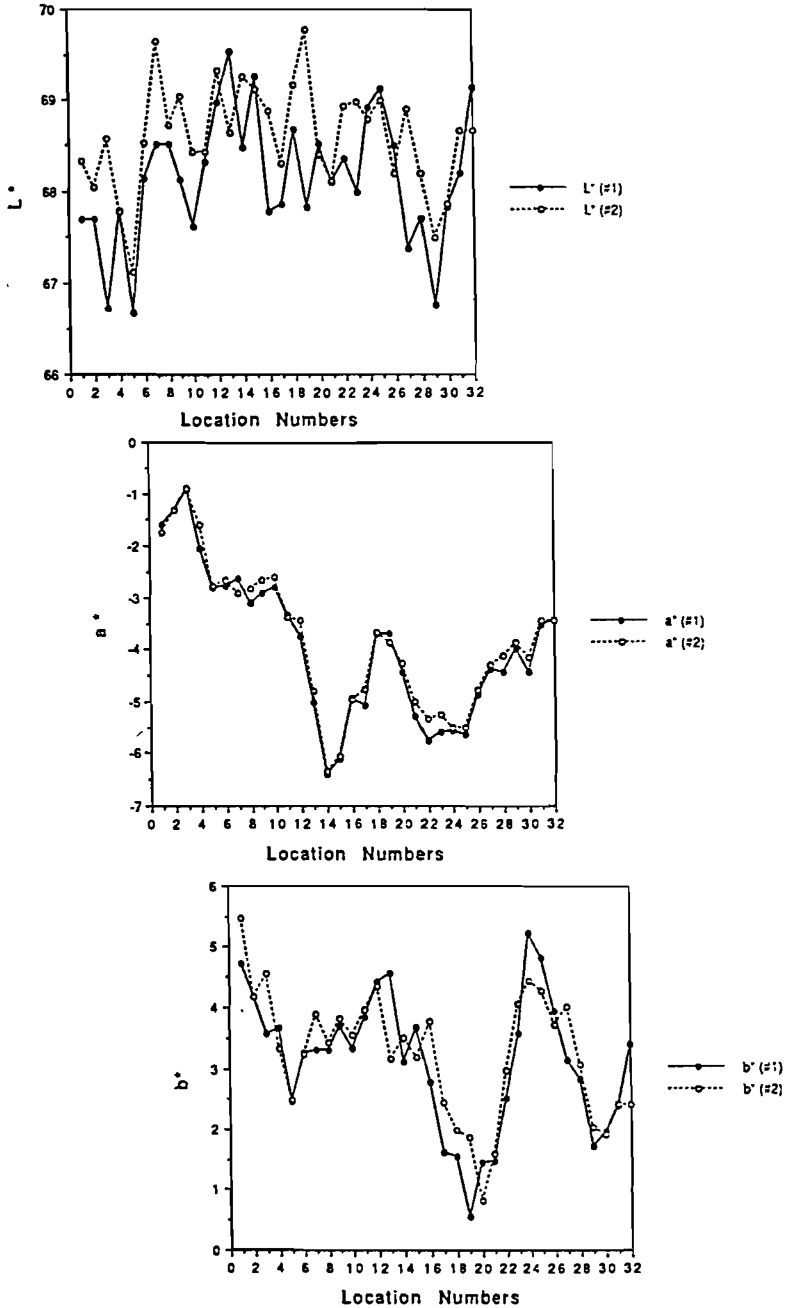

Figure 3 Values of L*, a*, and b* of 32 measurements on each of two consecutive printed copies are plotted versus the measuring locations.

Effects of Press Variables on (L*, a*, b*)

Cold Start

Several sets of cold start data were collected from our printing runs. One set is shown in Figure 4 and Figure 5. In this run, the press speed was 15,000 impressions/ hour. Three consecutive copies were collected at a sampling period of 250 impressions; data plotted in Figure 5 are the average values of three copies. During the press runs, temperatures were measured at various locations, for example, on the bearing collars on the operator side and on the drive side of the impression cylinder, the blanket cylinder, and the plate cylinder by using thermocouples. Meanwhile, temperatures on the plate cylinders were also monitored by using an IR temperature sensor. In general, temperatures at these locations increased during start up; for example, on the operator side of the impression cylinder, the temperature increased from 70°F to 80°F, while about 10,000 impressions were printed.

Fitted curves are shown in Figure 4 (a), (b) and (c) for L*, a* and b*, respectively, to illustrate their general trends for this particular set of data. Each of these figures contains four curves for measurements at four different locations corresponding to ink key #4, #7, #17 and #20 (the UOP has 24 ink keys across the web), where the key #4 is near the drive side of the press, and #20 the operator side on the yellow and magenta units. The triplet values at key #4 and #20 are plotted in Figure 5 (a), (b) and (c), as well as in Figure 6 (a), (b) and (c), respectively, to illustrate the nature of the data. Figure 7 (a) and (b) plot the data from two separate cold-start tests; the data in Figure 7(a) were obtained by measuring at the location corresponding to ink key #4, while the data in Figure 7(b) were obtained by measuring at the center of the gray bar on the right-hand page of the test form.

From the printing experiments, we observed that L*, a*, and b* values change as a function of printing time during cold start. The effect may be due to the changes in press temperature since ink key settings and dampener settings were kept constant during each press run. Meanwhile, the effect on the right-hand page of the test form seems more significant than on the left-hand page. (On the UOP, the right-hand page of the test form corresponds to the drive side of the press. The drive on the press is considered as a major source of heat.)

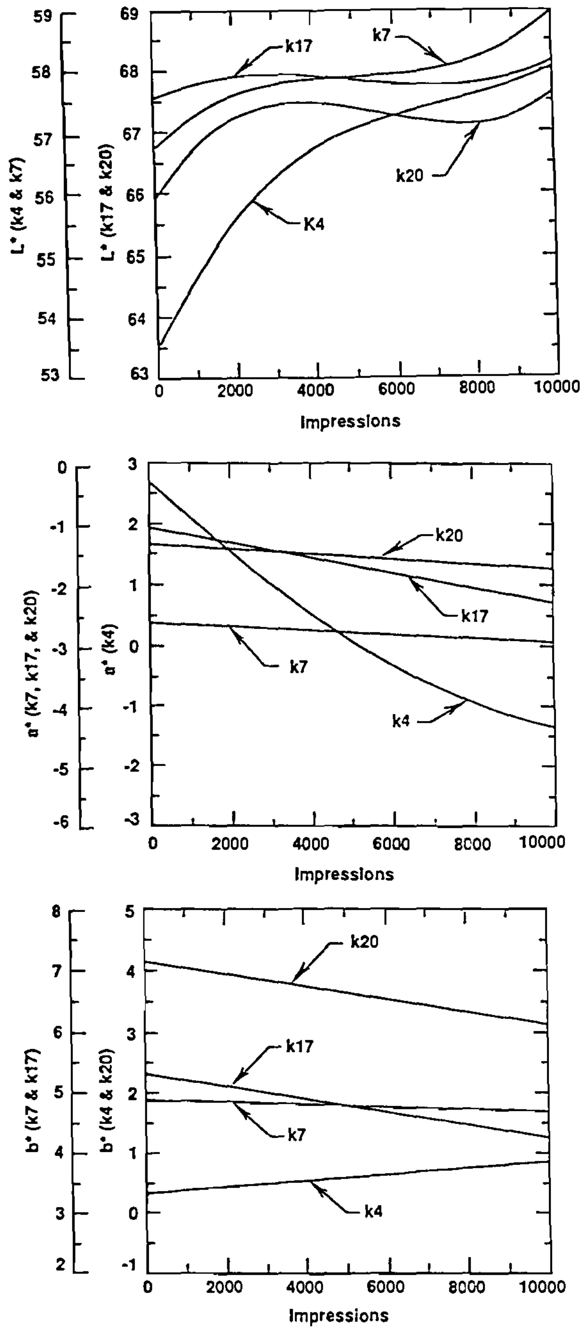

Figure 4 Color changes during a cold start, which were measured at four different locations.

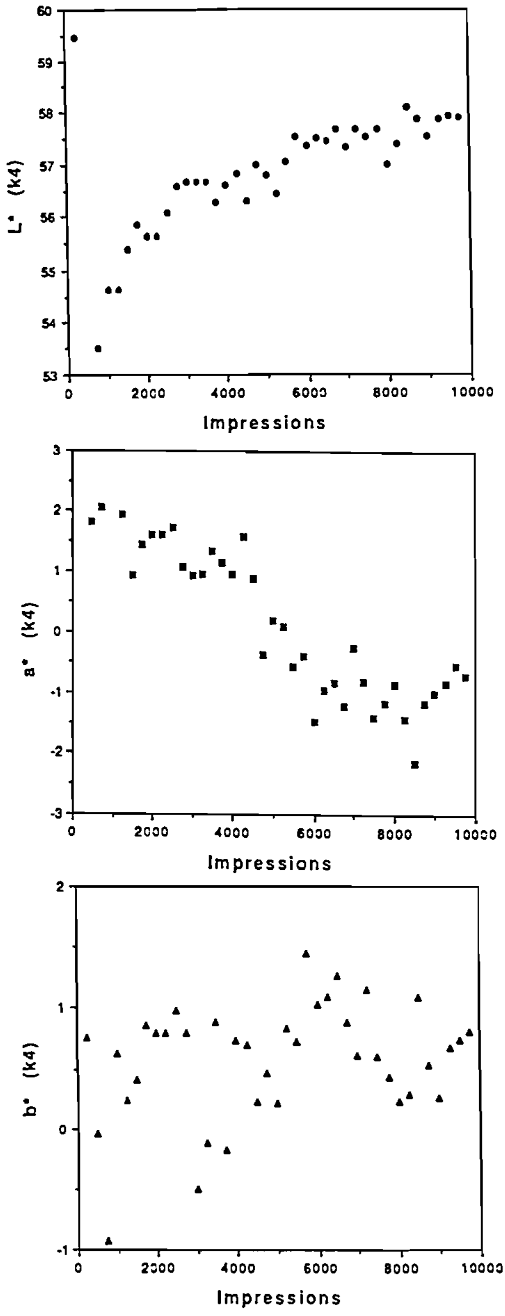

Figure 5 Raw data of L*, a* and b* for the measuring location corresponding to ink key #4 from a cold start test.

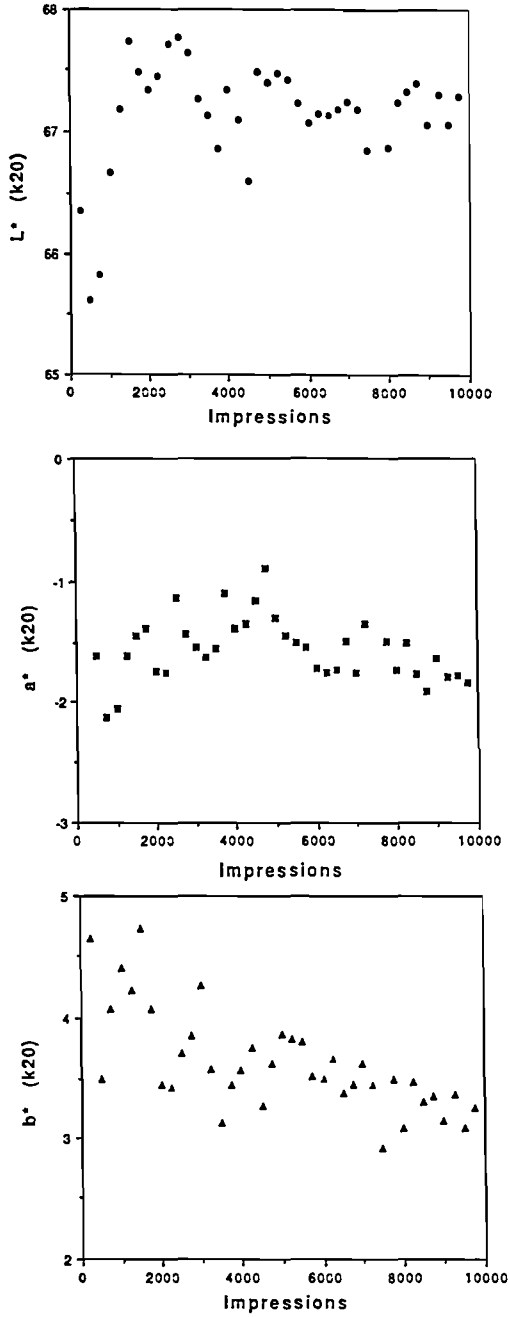

Figure 6 Raw data of L*, a* and b* for the measuring location corresponding to ink key #20 from a cold start test.

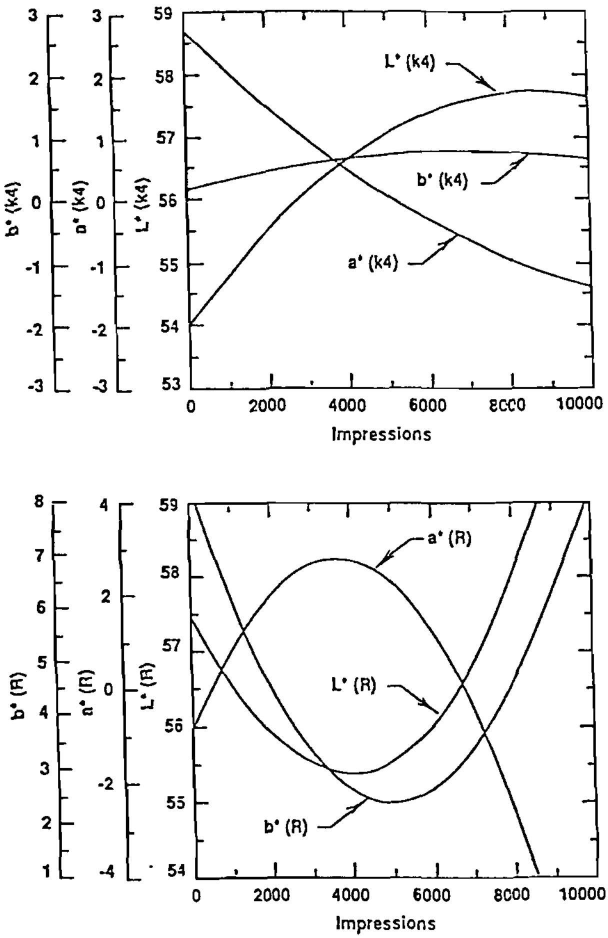

Figure 7 Color changes for two separate cold start tests. Colors were measured at two different locations.

Press Speed

Although several tests were conducted in which the press speed was varied, here we report only one set of results. Figure 8 plots L*, a*, and b* as a function of press speed. In the speed range we studied, i.e., from 8,000 impressions/hour to 20,000 impressions/hours, the variations in L*, a* and b* values were observed. L* had an increasing trend as a function of press speed. Meanwhile the trends for a* and b* were also clear; however, they were not consistent between the two sides of the test form.

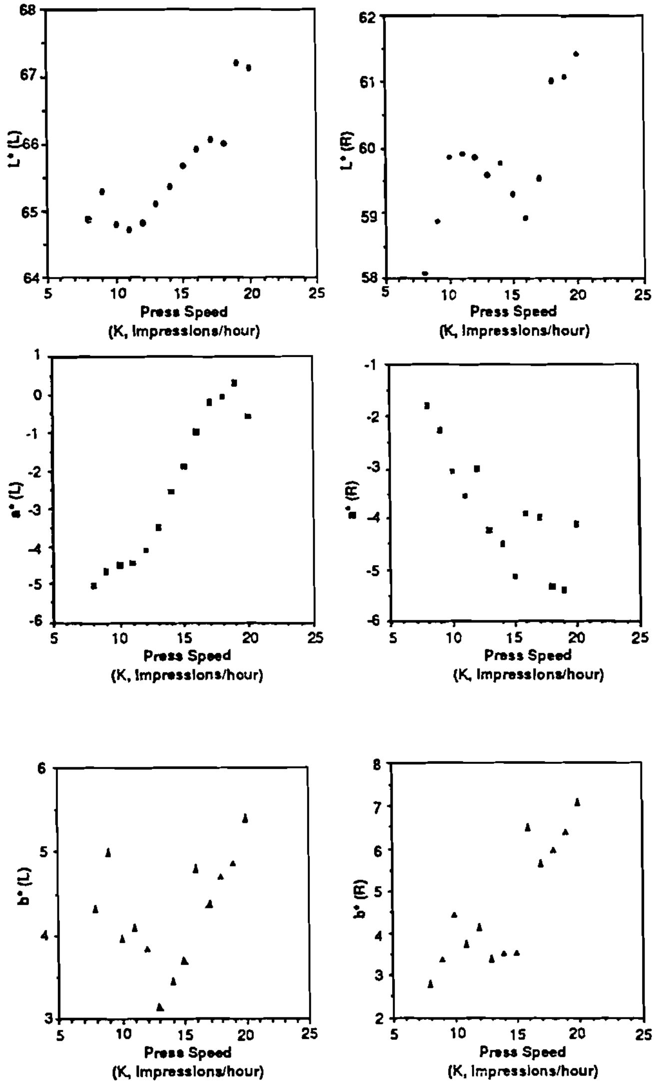

Figure 8 L*, a* and b* vs. press speed. (L represents the left-hand page of the test form, while R represents the right-hand page.)

Dampener

Similarly, several printing tests were conducted in which the dampener settings for yellow, cyan, and magenta inks were varied individually. The adjusted range for each dampener covered from scum to wash. Table 2(a) shows the L*, a* and b* variations as the dampener for yellow was varied from 2.0 to 4.2, 2(b) for magenta from 2.2 to 4.4, and 2(c) for cyan from 2.4 to 4.0. Only one dampener was adjusted each time. When the dampeners were not adjusted, they remained in the same settings throughout the test: 2.8, 3.0, and 2.8 for yellow, magenta, and cyan, respectively.

Although changes in L*, a*, and b* values were observed, the trends were somewhat confusing. Some observations can be explained reasonably, while some others cannot; it may be that some variations in some process variables, e.g., the press temperature, were not accounted for properly.

Table 2 Color changes due to the changes of dampeners.

Table 2(a) Changes of yellow dampener while magenta and cyan dampeners remained unchanged. T is the temperature (°F) at operator side of impression cylinder.

Dampener	Key 7 Location			Key 17 Location			T
Setting	L*	a*	b*	L*	a*	b*	
2.8	58.15	-8.19	-3.18	67.74	-5.51	1.83	81
2.0	58.70	-8.01	-3.51	66.59	-7.17	6.66	82
2.2	58.32	-8.65	-3.43	66.94	-6.27	4.27	82
2.4	58.63	-8.73	-2.71	67.69	-5.66	3.90	83
2.6	58.94	-7.81	-2.30	67.31	-5.66	2.16	83
2.8	58.63	-8.46	-2.74	67.49	-5.14	1.59	84
3.0	58.91	-8.08	-2.73	68.33	-4.21	2.25	84
3.2	58.76	-8.97	-2.75	68.44	-3.83	1.99	84
3.4	58.94	-7.74	-2.29	67.54	-4.59	0.99	84
3.6	59.72	-7.41	-1.00	67.67	-4.34	1.01	84
3.8	59.54	-7.77	-0.61	68.34	-3.96	1.94	85
4.0	59.70	-7.78	-0.78	68.35	-4.57	1.95	85
4.2	59.81	-7.17	-1.00	67.80	-3.92	2.08	85

Table 2(b) Changes of magenta dampener while yellow and cyan dampeners remained unchanged. T is the temperature (°F) at operator side of impression cylinder.

Dampener Setting	Key 7 Location L*	a*	b*	Key 17 Location L*	a*	b*	T
2.2	61.03	-8.17	-0.72	67.35	-3.01	0.62	86
2.4	60.51	-8.72	-1.35	67.83	-3.27	1.50	86
2.6	60.73	-8.42	-0.99	68.12	-3.99	1.60	86
2.8	60.81	-7.96	-0.81	68.10	-4.30	1.82	87
3.0	60.12	-8.16	-1.52	68.19	-4.53	1.89	87
3.2	60.91	-8.16	-1.01	67.98	-4.43	1.67	87
3.4	60.45	-6.75	-0.88	68.11	-4.27	1.77	88
3.6	59.86	-5.80	-1.03	68.75	-4.38	2.46	88
3.8	59.25	-5.29	-1.86	68.18	-4.09	1.68	88
4.2	58.79	-5.20	-2.28	68.68	-4.36	2.27	88
4.4	58.31	-4.70	-2.23	68.12	-4.64	1.63	88

Table 2(c) Changes of cyan dampener while yellow and magenta dampeners remained unchanged. T is the temperature (°F) at operator side of impression cylinder.

Dampener Setting	Key 7 Location L*	a*	b*	Key 17 Location L*	a*	b*	T
2.4	58.37	-3.97	-2.53	67.50	-4.99	1.29	86
2.6	59.80	-8.47	-1.65	67.29	-5.85	0.90	87
2.8	60.15	-7.38	-1.29	68.25	-4.45	1.76	87
3.0	60.35	-7.52	-1.07	68.15	-4.40	1.80	88
3.2	61.96	-6.62	-0.66	68.58	-4.20	2.38	88
3.4	61.05	-7.07	-0.57	68.69	-4.51	2.05	88
3.6	61.74	-5.74	0.61	68.99	-4.39	2.41	88
3.8	61.87	-5.36	1.03	69.50	-3.46	2.98	89
4.0	63.27	-3.48	2.88	69.85	-2.88	4.12	89

Discussion

Color variations during steady-state printing are derived from various sources: paper, ink-dampening solution combination, the colorimeter itself, and even the use of the colorimeter by the operator [3][4]. These factors characterize the statistical nature of steady state colorimetric measurements from a particular operation. For operators, or for the process control system, the data in Figures 1(a), (b), (c), and 2(a), (b), (c) represent the best possible tolerance that a control system can achieve in a steady state condition[5].

During the cold start, the press temperature had a more visible change than any other factor as the ink and dampener feedrates were not adjusted. Another transient which was less measurable was ink-water balance. While the increase of temperature should have an effect on the fountain solution consumption rate [6], the data showed an opposite trend; that is, L* values tend to increase and a* and b* remain more or less the same. The trend suggests that ink-water balance should play a role in print appearance[7].

Another temperature factor that affects the print during the cold start is the temperature slope on the press. The temperature slope caused by the driving elements, produces more heat on the driving side. Such a temperature slope is often the reason for problems in achieving uniform color reproduction over the whole sheet width, especially with multiple image printing.

The trend of color variations vs. press speed is clearer than vs. other variables. The data in Figure 8 can be used as a reference in determining dampener motor speed vs. press speed. The trends of a* for the right and the left are inconsistent. We attribute such inconsistence to a mechanical defect in the press.

If increasing the amount of dampener for an ink can be considered to have the same effect as reducing the amount of that ink, the effects of increasing the dampener setting for yellow, magenta and cyan individually on L*, a* and b* values can be assumed as described in Table 3. Some of the data in Table 2 do not follow the trend in Table 3 very well. It is suspected that the increase of press temperature may have accelerated the water consumption rate.

Table 3 The variations of L*, a* and b* caused by the increase of dampeners.

	L*	a*	b*
Y Dampener(+)	+	0	-
M Dampener(+)	+	-	0
C Dampener(+)	+	+	+

Y: yellow; M: magenta; C: cyan
+: increase; -: decrease; 0: no or little change

Concluding Remarks

In this paper we have presented the study of color variations during steady state and cold start printing, and also with changes of speed and dampener feedrates. It is evident that making adjustments without considering the statistical nature of colorimetric measurements and without accounting for the rate at which the process undergoes change is not as effective as making adjustments using information about these factors.

Due to the complex nature of the color printing process, it is difficult to explain what observed in the process outcome without carefully monitoring variations in press/process variables during a press run. Also, because of time-varyings and the uncertain nature of the process, it is apparent that an adaptive control scheme with on-line adaptation will be needed for effectively controlling the color printing process.

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