PRINT EXPERT(tm)

Alan R. Muirhead*

Abstract: The Print Expert(tm) is a new quality control tool for the printer. Its regulation technique is based upon a new concept, the color balance hexagon, which graphically shows any color shifts to the pressman. Unlike other print quality measuring systems, the Print Expert(tm) provides expert advice for changes in printing conditions needed to meet chosen specifications.

Introduction

The decade of the 1980's has seen tremendous growth in the use of quality control methodology in the printing industry. The increased use of measurement and control techniques has gone hand-in-hand with, and in many ways was required by, the tremendous growth in color pages that has characterized the last several years. Several papers in this year's meeting and discussions in the workshops have re-emphasized the need for quality control techniques and appropriate measurements in the printing industry.

The increased usage of measurements and quality control techniques has improved quality, consistency, and also the bottom line at many printing plants. But it is also true that some images or pages are still hard to print, even when dot gain and solid density are controlled within recommended guidelines, and a good pressman will find himself controlling the press by his own visual assessment of picture quality. Why is this so?

Perhaps it is because we have not been looking at measurement in the most effective way. We would like to suggest that the measurement techniques used in the printing industry to date are all

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*E. I. DuPont de Nemours Co. Inc., Imaging Systems Dept, Printing Systems Division, Chestnut Run 708, Wilmington, DE 19898

"process-related"; that is, we measure the variables such as solid ink density which are related to the process of printing. In the language of quality control, such process measurements are important, but even more important are "end-use" measurements, which in the case of printing means measurements that are more related to picture quality. We have traditionally lacked appropriate "end-use" measurements of printing quality that relate directly to the visual appearance of pictorials. So the questions become:

- what are the characteristics of an image that make it easy or hard to print?

- can we develop picture-related measurements of printing quality?

System Brunner Picture Contrast Classes and Printing Variability

The outline of a picture-based measurement technique was presented by Felix Brunner at last year's TAGA meeting. I will spend a few moments summarizing his findings.

Over the last several years, System Brunner has analyzed many hundreds of pictures to find the characteristics that determine whether a picture is easy or hard to print. Based on these characteristics, System Brunner has developed a combination of measurements which are better related to "end-use" picture quality.

Brunner recognized that an image's printability is governed by the nature and degree of internal contrasts. For example, pictures with little color or tone contrasts are very sensitive to printing variability--an extremely example is a flat tint, which will reveal almost any change in dot gain or solid density. At the other extreme are pictures with many differing colors and tones--in other words, pictures having high internal contrasts. As Brunner described last year, we use the phrase Picture Contrast Classes to describe

this situation. Picture Contrast Class 0 refers to the low contrast extreme and Picture Contrast Class 3 to the high contrast extreme. Most pictures are class 2, presenting mixtures of color and tone contrasts. Class 1 pictures have less contrast or might have relatively large areas of sensitive colors such as flesh tones.

To determine which characteristics of picture quality are most critical, panels of viewers were asked to judge samples of pictures from each Picture Contrast Class which showed typical printing variability. Another goal was to find what amount of variability was noticeable in each type of picture. Based on these results, three characteristics were found to be the most important: color shifts, overall picture gradation, and total contrast.

Color shifts were more readily detected by the panels than any other variation. The "human perception system" is most sensitive to color variation. In the offset process, color shifts are primarily caused by an imbalance or divergence of dot gains in the midtones of the three process colors, resulting in an incorrect color balance.

Of secondary importance is the internal picture gradation. By picture gradation, we refer to the average dot gain of the three process colors. Increases or decreases in dot gain which preserve the balance among all three colors change the internal gradation. For example, an increase in dot gain at the midtone will compress shadow contrast and increase contrast in the highlight through quartertone regions. A generally less critical characteristic is the total or overall contrast, that is, the density range from paper white to solid.

Print Expert(tm)

Based upon the precise identification of perceptible pictorial interrelations through picture analysis, a new picture-related measurement and control technique was formulated. This approach is embodied in a joint System

Brunner-DuPont development called the Print Expert(tm).

A major innovation included in the Print Expert(tm) is a color balance hexagon that shows color shifts in a color space based on dot gain differences among the three process inks. In fact, the color balance hexagon is used as the logo for the system. The black and white illustrations printed here show the different

Figure 1. Print Expert(tm) color balance hexagon.

colors as different tones: magenta is at the top, followed in a clockwise direction by red, yellow, green (at the bottom), cyan, and blue.

During a print run, color shifts are usually caused by "divergent" dot gains, for example, dot gain increasing in one color while decreasing in the others. The color balance hexagon expresses

color shifts in a way that is easily measured and uses terminology that is common in the printing industry.

The color balance hexagon we are using here should not be confused with similar diagrams the are based on densities or colorimetric data. The hexagon is graded as follows: the inner, thin lines represent a deviation of 1% dot gain from ideal color balance; the next, thicker lines are 3% variation; the next, 5%; and the outer lines represent a 7% variation. Thus amount of any color shift is immediately apparent to the pressman.

The steps in the color balance hexagon are also related to the Picture Contrast Classes discussed earlier. The results of the viewing panel trials revealed that color balance variability of as little as 1% was very noticeable in pictures of Class 0. Thus allowable variability in printing Class 0 pictures lies within the innermost hexagon. Moving outward, the acceptable variability for Class 1 pictures falls within the next hexagon, and so forth.

The importance of this system of analysis is that it represents an objective way of determining the quality of printing necessary to reproduce a given picture. Communication along the chain from customer to printer is improved. In earlier control systems, color balance was visually estimated from balance patches. But the exact degree of color balance in the midtones and shadows is required for evaluation of corrective action on press or adjustment of separation films. The color balance hexagon displays the exact amount of color shift or imbalance in terms of dot size change, facilitating any adjustments that need to be made.

Another innovation included in the Print Expert(tm) is a simplified measurement technique. Utilizing a highly-stable third-decimal place densitometer, all necessary information can be derived from measurement of midtone and shadow gray balance patches only. This cuts by two-thirds the number of readings needed to

characterize color balance, picture gradation, and total contrast compared to using conventional single color tint and solid patches. The necessary gray balance patches are part of the new Print Expert(tm) control strip. Other elements, including 25%-50%-75%-solid patches in each color, overprints, and others, are also present in case further analyses are needed.

Regulation diagram

In operation, the Print Expert(tm) presents all measuring values relevant to the picture in a compact display that we call the regulation diagram. This example shows readings taken in

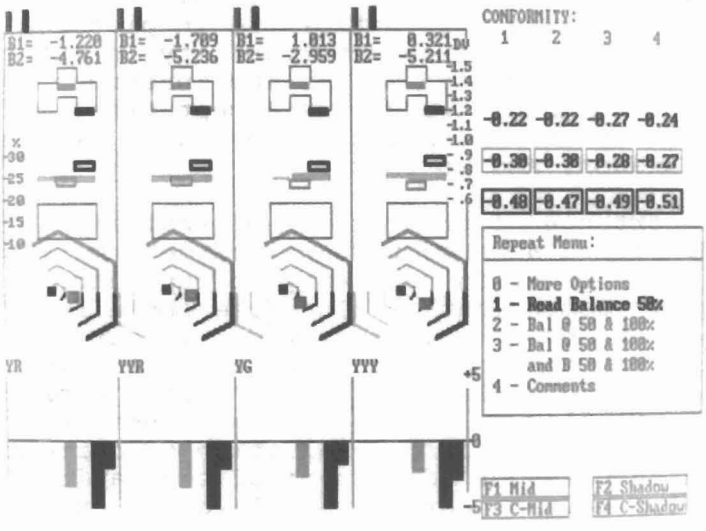

Figure 2. Regulation diagram showing all four zones.

four areas or zones across the sheet. If we look at the regulation diagram for zone 1, we see that

it consists of the color balance hexagon and tolerance windows for picture gradation and total contrast. The bar graphs and table are part of the Print Expert's recommendations for improving the printed result and will be discussed below.

Turning to the color balance hexagon, the position of the gray square in shows immediately a midtone color shift in the yellow-red direction of a total of two percent. The amount can be read off from the color balance hexagon or from the letters below: each letter represents one dot percent. Color balance in the shadow is indicated by the white square; it is very slightly to the cyan-blue.

Above the color balance hexagon is the tolerance window for picture gradation. The scale is dot percent, shown on the left. Overall picture gradation is calculated from the average of the dot gain of yellow-magenta-cyan, and is plotted as the gray bar. Individual dot gains are symbolized by the open or outlined rectangles in the appropriate color. The boundaries of the window are determined by the aimpoints chosen for the particular print run, for example SWOP or an internal house standard. In this case, picture gradation is considerably higher than the range specified for this print run.

Near the top of the display is the tolerance window for total contrast, that is, net solid ink density. Again, the limits for the window are chosen for the type of print run. The solid rectangles correspond to the values for each ink. In this example, solid ink densities are in the tolerance window, although yellow is at the bottom of limits.

The black printer was not read in these examples. If it had been read, the black dot gain and solid ink densities would be displayed to the left of the tolerance windows.

The four regulation diagrams arranged side by side provide a complete overview of the print sheet. The overview is important because during make-ready and press time, instant monitoring of color

balance, picture gradation and total contrast in each picture zone is crucial to the pressman.

Expert functions

The Print Expert(tm) goes beyond simply displaying these picture-related results by advising the pressman on any necessary adjustments. For example, given the yellow-red shift here, the pressman could choose to reduce yellow and magenta or even increase cyan. The Print Expert(tm) calculates the best adjustments to maintain optimum color balance while also adjusting picture gradation and total contrast toward the center of their respective tolerance windows. The bar charts at the bottom show whether dot gain should be increased or decreased for each color and by relatively how much. In this example, the recommendations are to decrease dot gain of all three colors because picture gradation is high. To improve color balance, yellow should be decreased the most, as indicated by the double bar. Magenta follows, with cyan decreased the least. In some pictures, a regulation scheme based on the midtone is not always appropriate. The Print Expert(tm) allows other schemes favoring the shadow to be selected by the operator.

These regulation recommendations provide dependable color control in several colors simultaneously. The pressman is able to eliminate the purely visual trial-and-error approach to controlling the press.

The conformity table in the upper right of the display presents the deviations from aim expected for solid ink density if color balance and picture gradation were optimized merely by changing the ink feed. Deviations greater than 0.15 are shown in red to emphasize that the print run is far out of specifications and major corrective action is needed. In these examples, all conformities are shown in red because of the high picture gradation. To correct the gradation by simple ink flow adjustments would likely result in very low total contrast or solid ink density values. Large conformity values such as these indicate that

fundamental changes need to be made, such as changing the blanket or adjusting the inks.

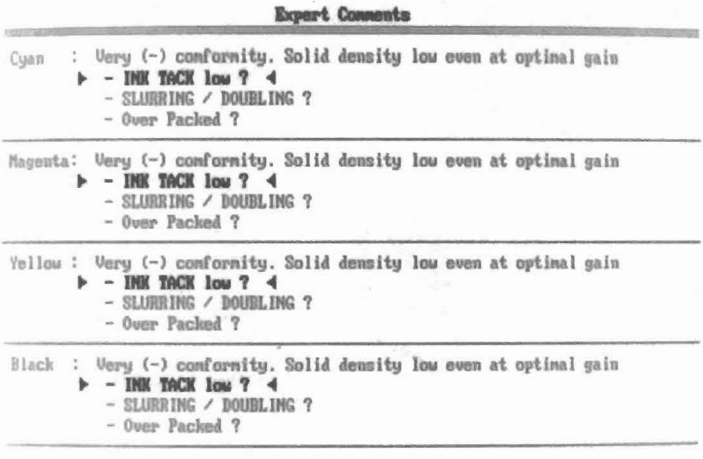

Figure 3. An expert comment screen.

The Print Expert(tm) offers expert advice on what areas should be examined to correct any problems. Simply pressing a "hot key" brings up suggestions for further investigations, based upon the actual printed results.

Other features

In addition to the regulation diagrams, production record information is presented together with

statistical analysis of uniformity. The tolerance hexagon displays color balance results for every

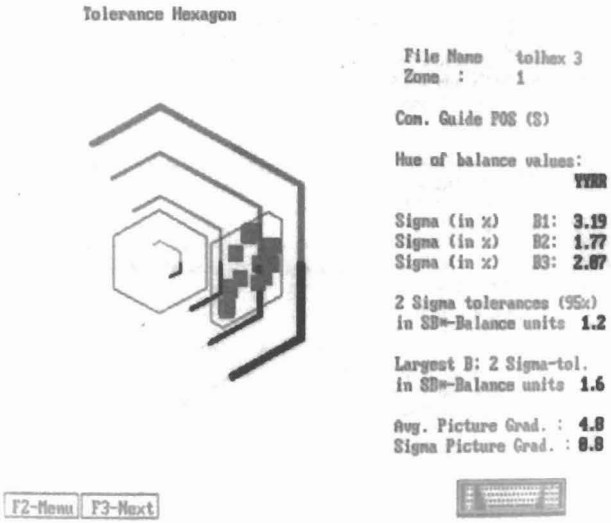

Figure 4. Tolerance hexagon showing color balance shift throughout print run.

measured sheet with the gray squares, and the pink square (light gray in the figure) indicates the average color shift of the whole print run. The irregular polygon delineates the 95% confidence limits for color shift. In order to aid in understanding the meaning of the irregular polygon, the equivalent area regular hexagon is also plotted, in this case showing a overall variability of between 2-3% color shift. This means that variability was within the range needed to reproduce difficult class 1 pictures acceptably, although the entire production was shifted red-yellow.

A time line is also available for solid ink density and dot gain, along with average values and standard deviations to aid in statistical process control analyses.

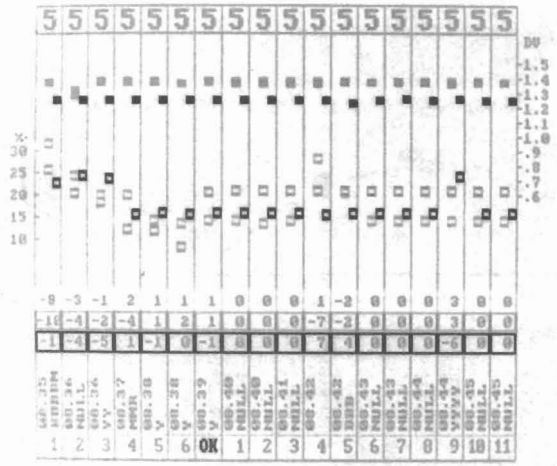

Figure 5. Production record of total contrast (DV) and dot gain from make-ready to ok sheet through production run.

Three point dot gain curves, including the critical 25% and 75% areas, can also be analyzed if necessary. The display of measured dot gain also shows typical printing performance and the theoretical Isocontour(tm) curves for reference.

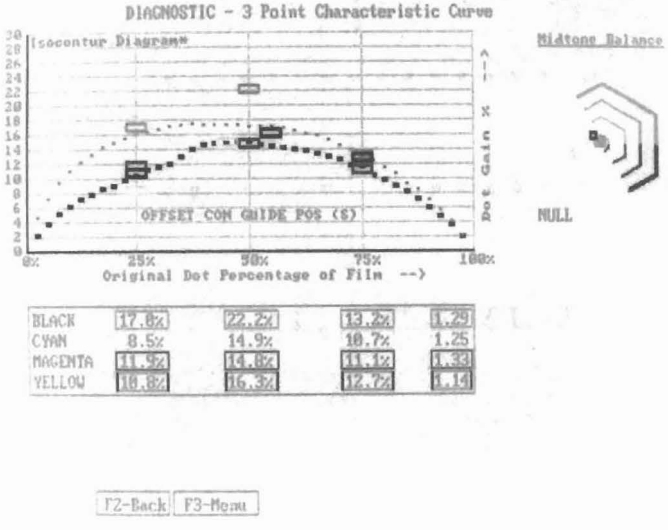

Figure 6. 3-point dot-gain curve.

The Print Expert(tm) is available in two basic formats--one for an office-like environment of a quality control area, and one featuring a special cabinet and computer that is suitable for the pressroom.

Figure 7. Print Expert(tm) for quality control area environment.

Summary

The Print Expert(tm) represents a new, picture-based measurement and control philosophy. By emphasizing color balance, it aligns with the most important visual attribute of reproduction quality. It allows extremely easy and fast measurements by deriving all parameters from gray

balance patch readings. Its expert features provide direct recommendations to the pressman for changes in inking and other press setup parameters. We believe the Print Expert(tm) is a significant advance in printing quality control efforts.

Literature cited

Brunner, F.
1987. "TAGA Proceedings" , pp. 256-263.

Figure 8. Print Expert(tm) for press room environment.