MEASUREMENTS of GRAY COMPONENT REDUCTION in NEUTRALS and SATURATED COLORS

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Abstract: An attempt is made to characterize Gray Component Reduction in a way which is scanner independent. In order to do this, we selected a series of colors and then prepared Matchprint patches which produced each of those colors. The selected colors contained neutrals at different luminances. In addition, there were some patches prepared representing saturated colors. For each color a series of patches were prepared. Each patch contained a different amount of black, but each patch of a given series produced the same color under standard illumination (D5000). In this way we were able to prepare plots for each color showing how much black is required to replace different amounts of process ink.

The patches described above were remeasured using another illuminant. By using these measurements, we show how metameric errors in color depend on the amount of gray scale replacement. Theoretical arguments indicate that patches with a high degree of gray scale replacement should show the least amount of metamerism, but our measurements suggest that this is not a large effect.

Introduction

In recent years the use of heavy Gray Component Reduction (GCR) has become increasingly

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popular among printers. This popularity seems to be largely due to the introduction of new scanners, such as the Hell DC350 and the EIKONIX DESIGNMASTER[R], which are able to perform heavy GCR effectively. In spite of the many advantages of heavy GCR, however, there is still some reluctance to adopt it. One very real disadvantage of heavy GCR is that its use may cause a printer who receives films from many different sources to have difficulty in judging those films. This is partly because the films are generated in a new way, but also because each scanner manufacturer performs GCR in a different way. This lack of standardization, while irritating to the printer, is probably a good thing for now, since it's not universally clear just what the best form of GCR actually is. Because each scanner performs GCR differently, it would be useful to be able to describe Gray Component Reduction in a way which does not depend on the way in which a particular scanner removes the process inks. The primary purpose of this paper is to present a series of graphs which summarize the ways in which GCR can take place in neutrals, and in a small set of saturated colors. By using these graphs a person should be able to judge whether a given set of films is or is not actually in balance.

The secondary purpose of this paper is to present a set of measurements showing the effect of GCR on metamerism. Since the use of different amounts of black leads to outputs with different spectra, it is reasonable to suppose that the way in which the appearance of a printed page changes with illumination can be influenced by the degree of GCR. Our measurements point to modest effects. Patches of the same color having very different amounts of black may differ in color by 1-2 jnd's when measured under very different illuminants. Spectral reflectance measurements of such patches will be presented in explanation of these results.

Presentation of the GCR Measurements

The first figure shows the effect of GCR for a set of neutral colors. Because our way of presenting our data is unfamiliar, I will describe the plots themselves before I describe how the plots were generated. Each set of plots represent a particular chrominance value. The chrominance shown in Figure 1 is the chrominance of King James white paper as measured under a D5000 illuminant. The units we are using to measure chrominance are from the 1961 CIE uniform color space (Luv). Each curve in the plot represents a fixed output density. By output density, I mean the logarithm of the photopic luminance of the final proof or press sheet. The curves in Figure 1 represent densities of .7, 1.0, 1.3, and 1.6. The curves indicate how cyan, magenta, and yellow vary with black for a given output neutral density. As an example of how these plots should be read, suppose one wished to know how to print a neutral with an output density of 1.0, using 20 percent black. An output density of 1.0 is indicated by the second curve from the bottom on each of the three graphs. By seeing where each of the three curves intersects the point indicating 20 percent black, one can read off the amounts of cyan, magenta, and yellow which must be combined with 20 percent black in order to produce the desired color.

Gray Component Reduction is often described as a method for removing process inks. There is another way of looking at GCR. The purpose of a press is to produce a particular color using some combination of the standard inks. Because there are four inks but only three independent colors, there is a degree of freedom in how the inks can be chosen. This can be seen in the plots, where each particular color can be represented by a curve in ink space. In theory, any particular color could be produced using any inking on its curve. As a practical matter, however, it is necessary that the black inking used for each color be only a little different from the black inkings used for neighboring colors. Thus, any particular method for performing GCR could be represented on these graphs by a trajectory going through each of the curves. A scanner producing a skeletal black (no GCR) would use a trajectory which passed through the bottom end points of these curves. A scanner which produced full GCR

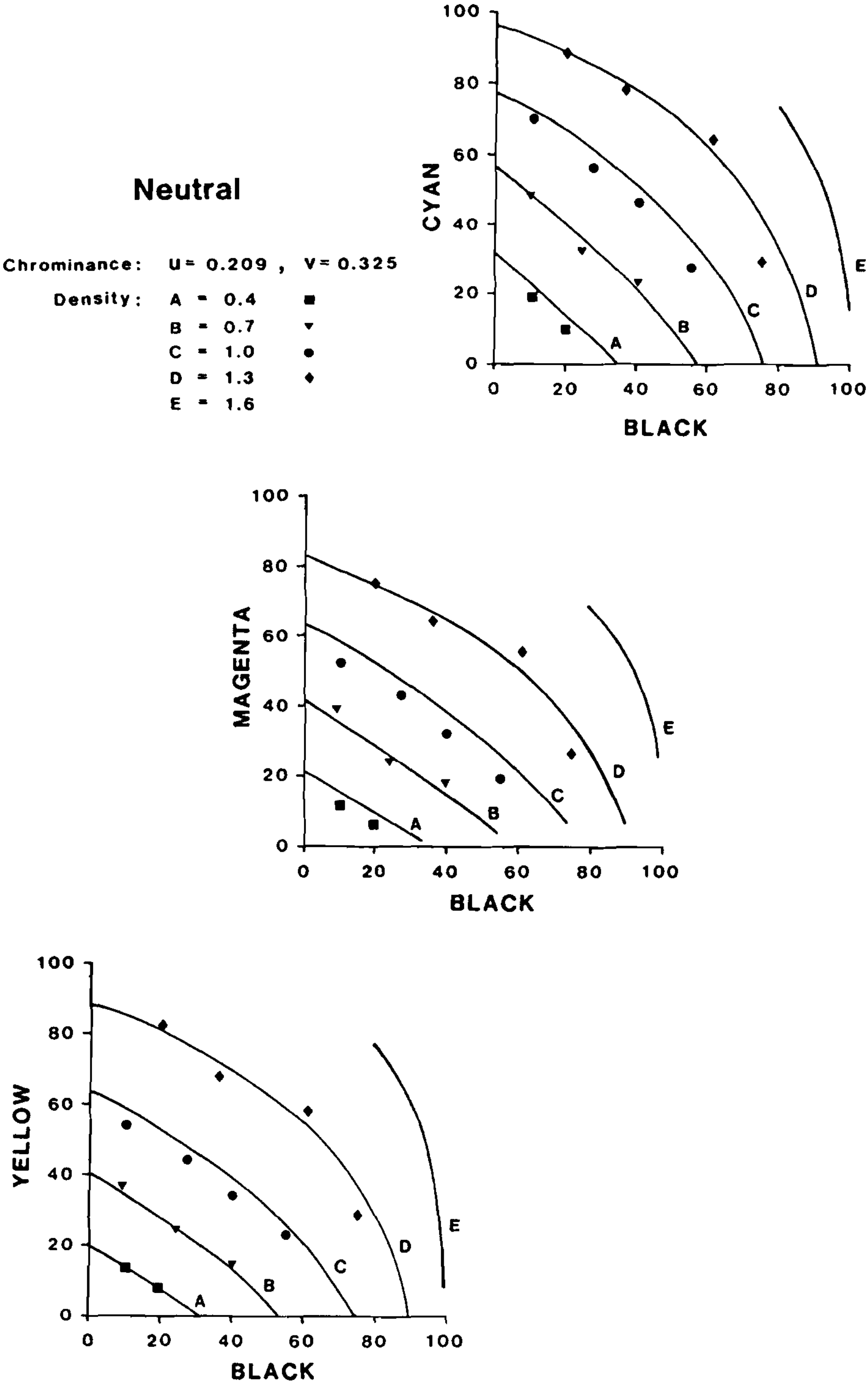

Figure 1. Process inks as functions of black for neutral chrominance.

("achromatic color") would use a trajectory which passed through the top end points of the curves.

The curves were derived using a colorimetric model for inks developed at EIKONIX by the authors and by Andrew Masia and Robert Chidlaw. This model is similar to the Neugebauer model. It differs from the standard Neugebauer model in that it allows for optical dot gain by employing terms which model the diffusion of light within the paper. The parameters used in this model were derived for 3M Matchprint and all our experimental data is based on that proofing system. The curves were produced by combining the model with a search procedure to find which inkings would produce a given color.

The experimental points shown on the plots were derived in an iterative way. We chose initial values from the theoretical curves. We then wrote films containing test patches whose inkings had the initial values, along with other test patches whose inkings differed slightly from the initial inkings. Once all these test patches had been proofed, they were measured with a colorimeter (Photo Research SpectraPritchard 1980A). We also measured the percent dot values on the films. Because of inaccuracies in our model, the measured colors of the test patches were not exactly equal to the values indicated on the graphs. Based on the measurements of these patches, we calculated new patches whose measured chrominance and luminance were closer to the desired values. Some of the measurements come much closer to the theoretical curves than others. It is worth pointing out that this is partly attributable to the fact that, in calibrating our model against colorimetric measurements, we strive to keep within a criterion error in color, not in ink. Accordingly, larger errors in ink are tolerated where color does not depend as critically on a particular ink.

The next several sets of measurements are for a moderately saturated cyan, a magenta, and a mixture of cyan and yellow (Figures 2, 3, and 4). As can be seen from the plots, the range of black values available for each of these colors is

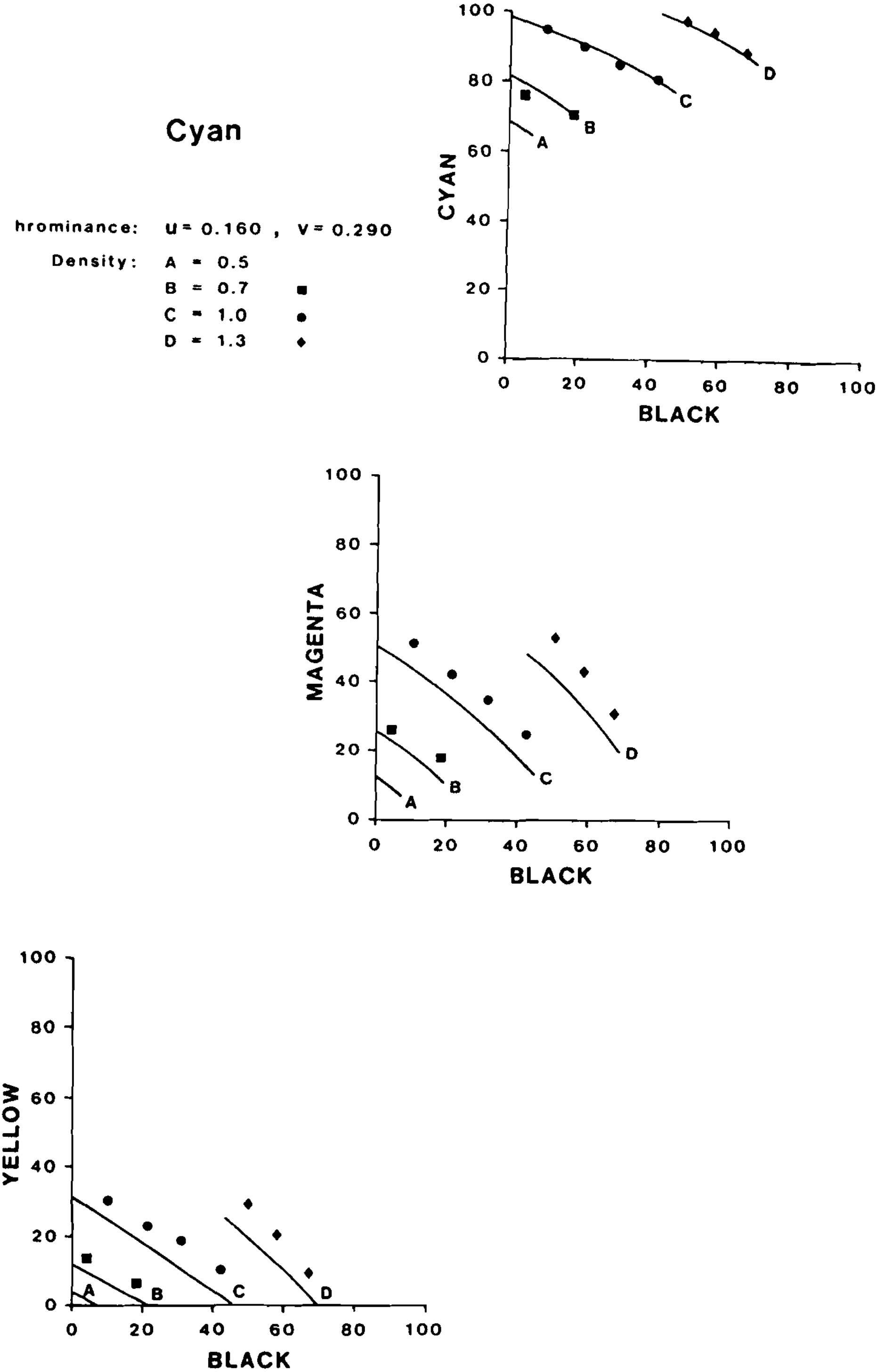

Figure 2. Process inks as functions of black for a cyan chrominance.

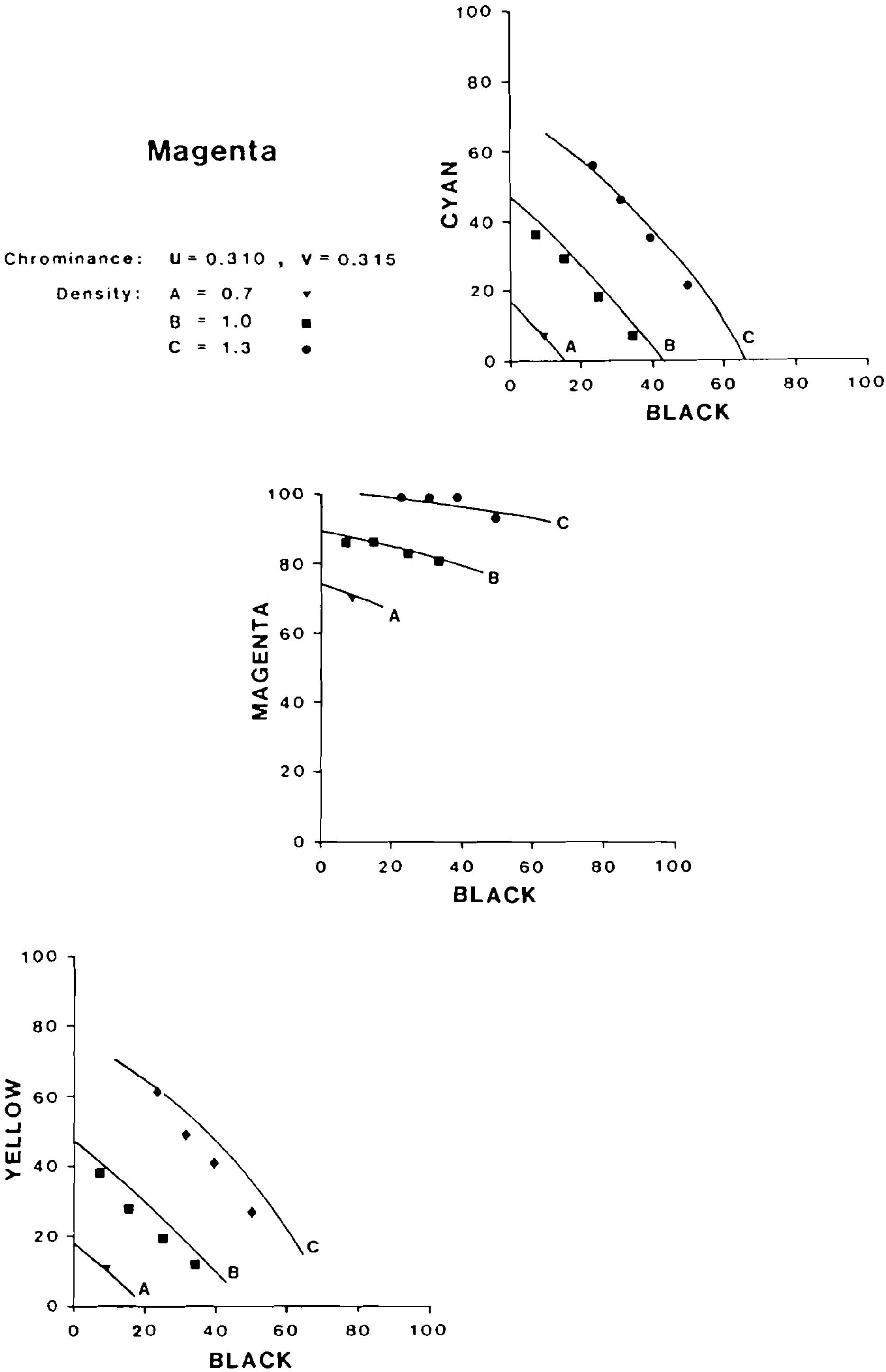

Figure 3. Process inks as functions of black for a magenta chrominance.

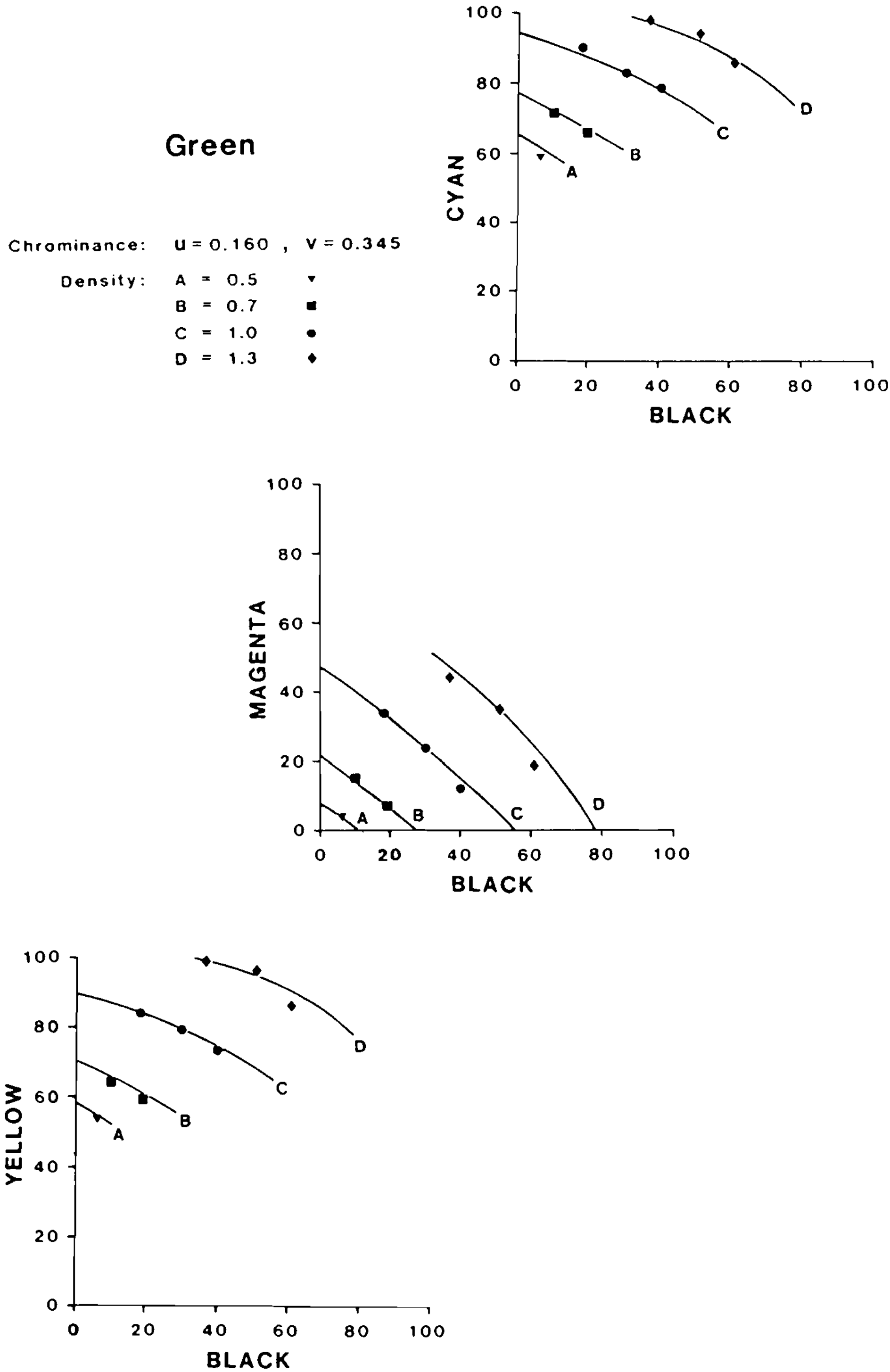

Figure 4. Process inks as a function of black for a green chrominance.

smaller than the range of blacks available for a neutral. It is also true, though not immediately apparent from the plots, that the proportions of cyan, magenta, and yellow in the "undercolor" or process gray component differ from the proportions in neutral colors. Facility in coping with this fact is one advantage of a colorimetric approach to GRC.

Metamerism

Perhaps the most conspicuous advantage of heavier GRC is the economy afforded by being able to use less cyan, magenta, and yellow. It is reasonable to suppose that another advantage lies in enhanced immunity to effects of metamerism. A neutral produced only with black ink would have a relatively flat spectrum, while a neutral reproduced only with cyan, magenta, and yellow would have a spectrum with three peaks. Therefore, one would expect that the neutral composed of black ink would more likely remain neutral in appearance under a wide variety of illuminants. Likewise, the appearance of a saturated color would be expected to remain more stable under different illuminants if it contains more black ink.

In order to test these notions we remeasured some of the ink patches using a household incandescent lamp as the illuminant. Figure 5 summarizes results for neutral chrominance. The W's mark the chrominances of 0 percent of all inks (Matchprint laminates) on King James stock as measured under a nominal D5000 and under a frosted tungsten lamp. Squares represent results for two patches of nominal 0.4 output density having 12 percent and 22 percent black ink. Circles stand for measurements of patches having a density of 1.0 and blacks of 15, 30, 45, and 60 percent. Diamonds represent results for patches of 1.3 density and 40 percent and 80 percent black.

In the absence of model error, measurement errors, and metameric effects, all points should lie atop the white points. Since the ink model was originally calibrated using the D5000 illu-

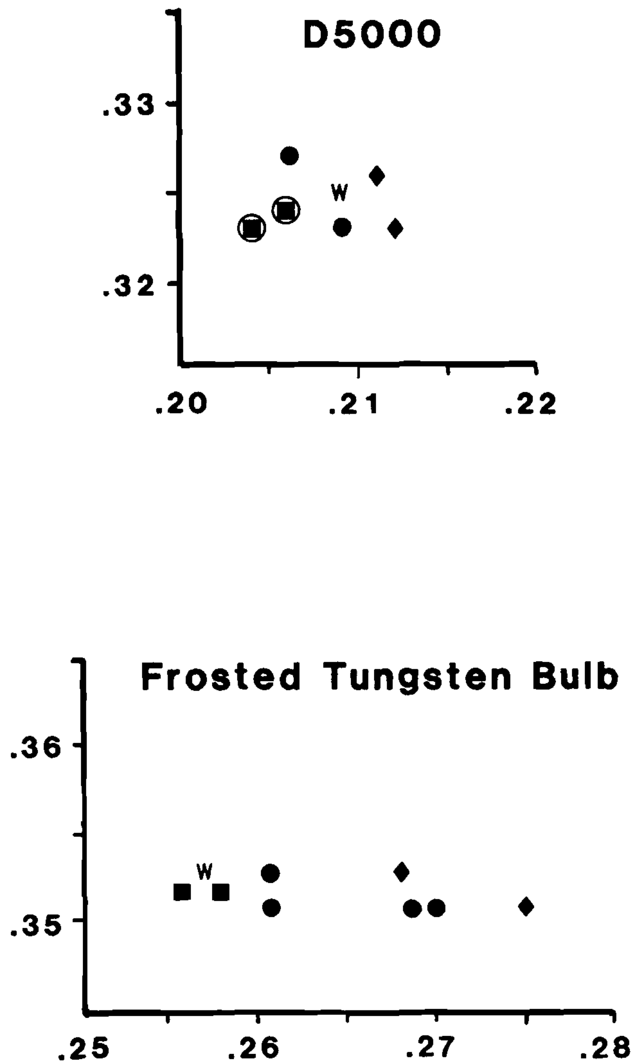

Figure 5. Metameric measurements of neutral patches.

minant, it is reasonable that data for various densities cluster about the white point and define the variation due to measurement and patch color calculation procedures. The tungsten data in Figure 5 illustrate three metameric effects: (1) the scatter in the color of patches is about twice as great as for D5000 at each density, (2) there is a shift in the red direction (relative to W) that increases with density, (3) at any density, the shift toward red is greater for patches having less black ink.

Figure 5 is representative of results for cyan, magenta, and green patches as well.

The color shifts reported here are likely to be just noticeable under "normal" viewing conditions. That metameric effects were not more pronounced surprised us somewhat, and suggested that the cyan, magenta, and yellow dyes might be more broadband in their absorption than we had imagined. Figure 6 shows spectra (measured with an EG&G Gamma Scientific spectroradiometer) for the two patches of 1.0 density which had 15 percent and 60 percent black, respectively. The 60 percent function is flatter, but not dramatically so. The large spikes in the spectra originate from the D5000 illuminant.

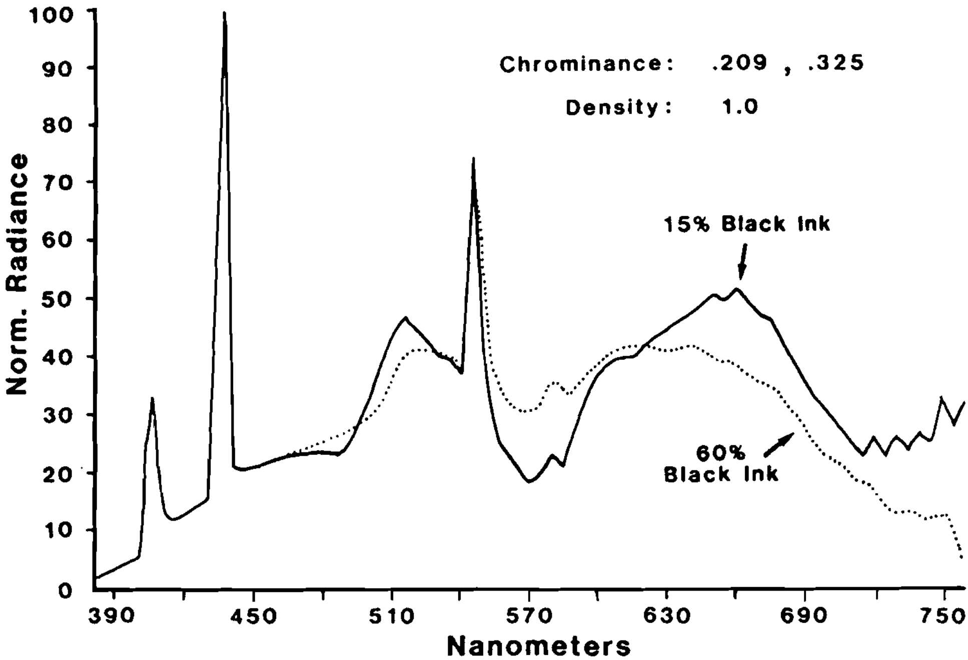

Figure 6. Reflection spectra for light and heavy GCR.