COLOR SPECIFICATION METHODS

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Abstract: A review of the non-quantitative methods of color specification for the graphic arts industry. Ink-mixing sample books and printed color charts are identified as the most important sample-based methods of color specification. The pitfalls of using verbal descriptors for color specification are discussed along with recommended procedures for indicating color changes on proofs.

Introduction

Color communication may be achieved through the use of numerical descriptors, physical samples, or verbal descriptors. For the sake of convenience, the use of numerical descriptors will be classified as color measurement and will not be discussed in this paper. The use of physical samples and verbal descriptors will be referred to as color specification.

The process of color selection and approval in the printing industry generally involves interaction between customer, color separator, and/or printer. Apart from the possible specification of inks, and the use of numerical control limits for proofs or printed sheets, measuring instruments such as colorimeters or densitometers are rarely used to specify color. In practice, printed color samples are commonly used to specify color before the job enters the production system. Typically, verbal color descriptors are used to indicate desired changes on color proofs; that is, after the job is in the production system.

Color Sample Systems

One kind of color order system is that where a series of permanent colors are arranged in order on the basis of hue, saturation, and lightness. Such systems as

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Munsell and Ostwald are well known to most graduates of art and design schools. A review of this type of color order system has been published by Robertson (1984).

The Munsell system (for example) is an "absolute" color reference and communication method. Its value to the printing industry, however, is limited for the following reasons: a) few printers posess Munsell color books; b) some colors in the Munsell collection cannot be reproduced by conventional process inks and, conversely, process inks can reproduce some colors not in the Munsell collection; c) once a color is selected the printer must work out how to match it; and d) the steps between samples may not be close enough to precisely specify the desired color.

Very little, if any, use of the "absolute" type of color order system is made by the printing industry. The most common types of color sample systems used by the printing industry are "relative" systems where the sample colors are related to the inks, substrate, and production technology used to produce the samples. A clear advantage with such systems is that once a color is selected, a corresponding formula or set of halftone values provides information on how to achieve the color in practice.

The printing industry uses two types of color sample systems. In cases where inks can be mixed together to produce special colors for labels, logos, or other applications, the ink mixing type of color sample system is used. In cases where a special background color must be achieved through the use of process color screen tints, a halftone color chart system is used.

Ink Mixing Guides

The typical ink mixing guide consists of a series of solid colors that represent the effect of mixing standard base colors together in a given proportion. The base colors consist of anywhere between eight and ten chromatic inks plus white and black. Most mixtures in the guides do not contain more than three or four inks.

Ink mixing guides are produced to close tolerances by the designer of the ink mixing system. The guides are printed with normal ink film thicknesses on both coated and uncoated substrates. (A listing of sources for ink mixing guides and other color sample systems for the printing industry are included in the appendix.)

For purposes of illustration, the Toyo Color Finder System will be used to represent the ink mixing color sample systems. Table I presents the number of colors represented in the system together with the number of inks required to provide all the matches. The CIELAB data in Table II represents the coordinates of sample chromatic base and process inks.

Halftone Color Charts

The typical halftone color chart consists of a grid of colors that have been produced by overprinting halftone screen tints in three or four process colors. A common configuration for such charts includes a common base percentage dot value (for example, cyan) over all the squares in the grid while the percentage dot value of the second color (say, magenta) increases in a stepwise manner from zero to 100% down the columns while the percentage dot value of the third color (say, yellow) increases in a stepwise manner from zero to 100% across the rows. The next "page" in the system is identical with the exception of the common base color. The percentage dot value of the base color (cyan, in the example) would increase in a stepwise manner from zero to 100% from page to page.

The halftone color charts may either be purchased in printed form or can be generated by any printer with a set of master films. The "off-the-shelf" printed charts are cheaper, but the "custom made" charts are more accurate for a given printing company.

Apart from the characteristics of the sample colors, the overall design of the chart is also important. The approaches to color chart design can be illustrated by reference to current stock printed color charts.

The S.D. Scott Process Color guide is based on an 11 x 11 grid of colors. The first page in the guide consists of overlapping 100% to 0% columns of yellow and 0% to 100% rows of magenta. The next page is identical except for a 5% dot of cyan over each square in the grid. The third page substitutes 5% black for cyan. This pattern continues on subsequent pages until the limits of 80% black and 100% cyan have been reached.

Table I

Toyo Color Finder System

Group	# of Shades	Family	Color Finder Numbers
1	56	Purple/Red	CF 8001-8056
2	56	Red	CF 8057-8112
3	56	Red/Yellow	CF 8113-8168
4	56	Yellow	CF 8169-8224
5	70	Yellow/Green	CF 8225-8294
6	56	Green	CF 8295-8350
7	56	Green/Blue	CF 8351-8406
8	70	Blue	CF 8407-8476
9	70	Blue/Purple	CF 8477-8546
10	70	Purple	CF 8547-8616
11	52	Gray/Black	CF 8617-8668
12	9	Fluorescents	CF 8669-8677
13	1	Bright Blue	CF 8678
14	19	Pearlescent	CF 8699-8697
15	3	Metallic	CF 8698-8700

700 Total Shades

Colors		#	Totals
Process Colors	=	4	4
Base Colors	=	10	14
Secondary Colors	=	12	26
Fluorescent Colors	=	9	35
Metallics	=	3	38 Total Base Colors

Table II

CIELAB Data for Toyo Color Finder Base and Process Inks

CF Number	Name	L*	a*	b*
8042	G Geranium	38.85	75.83	8.20
8056	12 Geranium	42.64	75.99	2.20
8110	3 Bronze Red	54.42	67.31	51.41
8112	4 Bronze Red	55.26	65.48	57.41
8196	26B Yellow	85.29	-5.06	100.51
8210	G Yellow	87.70	-11.65	108.78
8350	79 Green	66.01	-64.19	1.61
8462	G Blue	46.83	-20.83	-52.41
8531	33 Bronze Blue	14.90	54.19	-63.03
8560	82 Violet	18.94	52.87	-59.43
8616	HS Geranium	34.53	77.53	-30.76

The next part to the Scott guide contains overlapping scales of cyan and black as the base with incremental tints of yellow or magenta being added for subsequent pages. The limits are 100% for both yellow and magenta. The guide contains coated and uncoated paper sections.

The Kueppers Color Atlas (1982) consists of an 11 x 11 base grid of overlapping magenta and cyan with black being added on a page-by-page basis up to a limit of 99% black. Additional parts of the Atlas treat the yellow and magenta overlaps and the yellow and cyan overlaps in a similar manner. A final section starts with the magenta and cyan grid and adds yellow page after page to a limit of 99%. This atlas is printed on glossy coated paper.

Dr. -Ing. Rudolf Hell GmbH (1985) has produced the Tonal Value Atlas as an aid for judging GCR color separations. Their atlas is based on a 12 x 12 grid and follows a similar pattern to the Kueppers Color Atlas. The Hell atlas is printed on dull coated paper.

The charts discussed so far can be particularly useful if the printing conditions for a given plant approximates that used for the stock printed chart. Apart from matching the reflectance and gloss characteristics of the paper and ink, the solid ink density, dot gain, color sequence, and trapping would also have to match in order for the chart to be a precise color guide.

The only stock color charts that are made to specific standard production conditions for a given industry are the Gravure Standard Color Charts (1984) produced by the Gravure Technical Association (now Gravure Association of America). The charts are produced to the Groups I, V, and VI specifications for stock, inks, and densities.

The GTA color charts consist of a 19 x 19 base grid of cyan and magenta. Yellow is added on a page-by-page basis up to the maximum density of 1.65. Overlapping grids of yellow and black, magenta and black, cyan and black, and red (yellow plus magenta) and black are also included in the chart.

A key problem with the stock color charts is that they may be unrepresentative of a given plant's printing conditions. Also, stock charts may be expensive if a plant purchases a large quantity for distribution to production workers, sales personnel, and customers. It is for these reasons that some printing plants purchase or produce master color chart film sets that they use to print their own color charts.

Companies have produced their own color charts in one form or another as long as there has been a color printing industry. However, the first known set of commercial master color chart films was not produced until comparatively recently (White, 1957). The Lithographic Technical Foundation (LTF) Color Chart consisted of a 6 x 7 base grid of yellow and magenta (there were only 6 levels of yellow). These grids repeated from left to right on the sheet for 7 levels of cyan up to a limit of 100%. This row of grids now repeated from top to bottom of the sheet for 6 levels of black up to a maximum of 75%. Two additional grids of the yellow-cyan and cyan-magenta gamut colors were also provided.

The LTF Color Chart was significant in that it displayed four-color overlaps on one sheet that measured 22" x 29". The chart design sacrificed the size of the color squares and the number of tone steps in order to keep the chart compact.

A design problem associated with the LTF Color Chart (and most other color charts) is that colors of similar hue are not adjacent to each other on the chart. In other words, the chart is not a color order system. The problem of color order was first solved by the Rochester Institute of Techology Process Ink Gamut (PIG) chart (Elyjiw and Yule, 1970). The PIG Chart is based on a hexagonal geometry and exhibits a smooth transition from hue to hue. The PIG Chart will only display gamut or limit colors, therefore, its use as a general purpose color chart is limited. A development of this chart, the RIT Elyjiw Color Palette, displays 900 colors, up from 218 on the PIG Chart.

A major breakthrough in color chart design was made by Carl E. Foss (Foss and Field, 1973; Foss, 1973). Rather than assembling screen tints in the simplest manner from the production viewpiont, Foss started with the user of the chart and worked backwards to devise a layout for assembly of screen tint films. His chart was based on the principle of a cubic color solid. By disecting the solid and developing the surfaces of the outer and inner cubes, it was possible to lay out a color chart that was a true color order system. A web offset version of the chart was also developed (Foss and Field, 1974).

The Foss system used nine tonal steps. The influence of the black printer was captured through the use of two black plates. The first black contained levels 0-3 and the second black contained levels 4-7. Each trichromatic square is divided into four in order to provide the black overprint. The entire system contained 5712 colors and the sheet-fed version fitted on two 23" x 28" sheets.

The other master color chart film sets currently on the market includes the Kodak Color Test Wheel and the ByChrome Color Selector Master Kit. The Kodak Color Test Wheel contains 216 colors arranged in a circle. Each color is printed at six tone levels except black which is not represented in the chart.

The ByChrome color chart consists of four master films: magenta with 12 steps declining from top to bottom; cyan with 12 steps declining from left to right, a 12 x 12 grid for the yellow; and, a 13 x 13 grid for the black. The yellow and black plates are made by laying a screen tint behind the appropriate grid when exposing the plates. The complete set of 132 charts requires one cyan plate, one magenta plate, eleven yellow plates, and ten black plates. The total number of plates may be reduced to 15 if the image is exposed 4-up on the plate.

The ideal color chart design should satisfy the following objectives.

* Color order. Colors of similar hue should be adjacent to each other on the chart.

* Black printer. The chart should contain one-color, two color, and three-color plus black combinations.

* Compactness. In order to minimize production costs, increase portability, and to simplify use, the chart should fit on one sheet of paper.

* Tone scale. Normal precision can be achieved with 9 to 11 tone steps. The scale should include a 5% step and exclude either the 90% or 100% step. Tone spacing should use as close to visually equal steps as possible. Table III presents the tone step spacing of the charts that were described earlier.

* Spacing between squares. The color squares in the grid should be close enough to each other to eliminate the illusion of dark spots where two white bars overlap. Alternatively, black bars may be printed between squares.

Table III

Color Chart Tone Scale Comparison

Tone Step	1	2	3	4	5	6	7	8
1	0	0%	0%	5%	0%	0%	0%	0%
2	1/16	15	5	15	5	5	5	10
3	1/8	35	10	25	15	10	10	20
4	1/4	67	20	50	25	20	20	30
5	1/2	100	30	75	35	30	30	40
6	3/4		40	90	50	40	40	50
7	Solid		50		70	50	50	60
8			60		85	60	60	70
9			70		100	70	70	80
10			80			80	80	90
11			100			90	90	99
12						100	100	

1 = LTF Color Chart
2 = RIT PIG Chart
3 = S.D. Scott
4 = Kodak Test Wheel
5 = Foss Color Order System
6 = Hell Tonal Value Atlas
7 = ByChrome Color Selector
8 = Kueppers Color Atlas

Another form of color chart is made up of transparent color overlay films. The films are made from commonly available color proofing materials and contain a pattern of increasing dot percentages of yellow, magenta, cyan and black.

One form of the color overlay system is in the form of a wheel or circle. As one of the yellow, magenta, cyan, or black overlay films is rotated, the displayed colors change to reflect the changing percentages of the color on the film in question.

The Murphy Color Wheel is one of the earliest color overlay types of color specifier. The major problem with the Murphy system is that the color order is lost as the overlays are rotated. This problem was overcome with the Norton Auto-Chromatic Wheel, a patented design (Norton, 1980).

The GATF Color Communicator uses four continuous halftone wedges of yellow, magenta, cyan, and black that are arranged in a linear configuration. By sliding the appropriate indicator from left to right, the user can observe the influence of increasing the dot percentage of the color in question.

The key advantage of the overlay film type of color guide is that the are dynamic systems rather than static displays of color. The dynamic nature allows thesimulation of many thousands of colors on a device that is quite compact and relatively inexpensive. A further advantage is that the influence of substrate color on the appearance of the printed color may be simulated by placing the substrate in question under the overlay films.

The main disadvantage of the overlay film type of color guide is that the displayed colors will not be as accurate a simulation of the final printed colors as an actual printed color chart. However, the overlay chart can be particularly useful when evaluating changes in overlay color proofs or helping customers to visualize the approximate effect of reducing or increasing dot sizes in a given area.

Verbal Description Systems

There are two situations where verbal descriptions are used for color specification. The first is in the initial selection of a color. For example, a customer may specify that "sky blue" be used for a particular background color. The other occasion is where a customer requests a change to an existing color. For example, a customer may specify that an area on a proof be made "more intense."

Several attempts have been made to relate the name of a color to a physical sample. One of the oldest references is "A Dictionary of Color" (Maerz and Paul, 1930) that contains over 3600 color names linked to printed color samples. A more recent reference is the Inter Society Color Council - National Bureau of Standards (ISCC-NBS) dictionary titled "The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names" published in 1955. This publication was reprinted in 1976 as "Color: Universal Language and Dictionary of Names" (Kelly and Judd, 1976).

The ISCC-NBS reference system links the names of color to the ISCC-NBS Centroid Color Chart, a collection of one-inch square glossy paint-on-paper samples. In all, there are 267 color name blocks (see Table IV and Figure 1) that serve as descriptors of color. The names of colors (e.g., "Daybreak") are referenced to the appropriate color descriptors (e.g., "Light Purple") which in turn can be specified in Munsell notation (e.g., anywhere between 3P to 9P hue, 5.5 to 7.5 value, and 5 to 9 chroma).

Another widely available system is the "Methuen Handbook of Colour." This reference (Kornerup and Wamscher, 1978) links 1266 printed colors to a list of color descriptors and color names. It has also been published in the United States under the title, "Reinhold Color Atlas."

While several references are available to aid with the naming of colors, no guidelines have been published to indicate how to specify changes in color that are typically made when marking up proofs. Indeed, many terms used in proof markup are often close to meaningless. A list of terms collected at a Research and Engineering Council roundtable discussion has been published by Bruno (1985).

The British publishing company, the Hamlyn Group, addressed the color proof correction issue by developing a set of proof markup symbols (Figure 2). The primary motivation for the use of symbols is to eliminate language differences that arise when conducting business in several European countries (Humphreys, 1973).

Table IV

Hue Names in the ISCC-NBS System

Red	Purple
Reddish Orange	Reddish Purple
Orange	Purplish Red
Orange Yellow	Purplish Pink
Yellow	Pink
Greenish Yellow	Yellowish Pink
Yellow Green	Brownish Pink
Yellowish Green	Brownish Orange
Green	Reddish Brown
Bluish Green	Brown
Greenish Blue	Yellowish Brown
Blue	Olive Brown
Purplish Blue	Olive
Violet	Olive Green

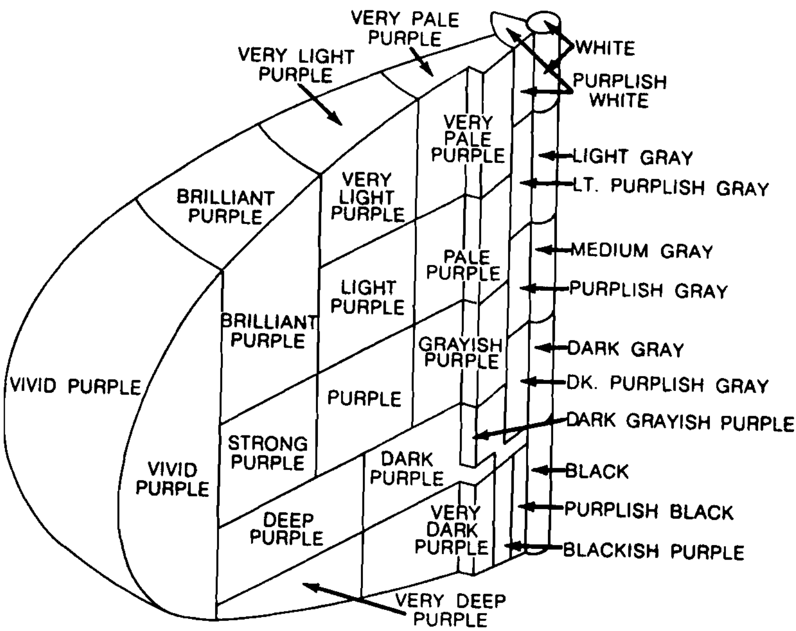

Figure 1. The Purple Hue Segment of the ISCC-NBS System

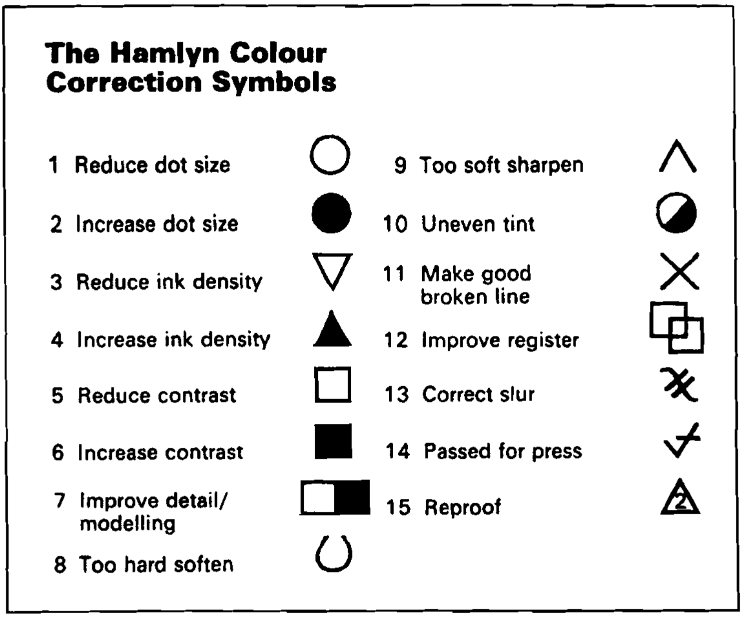

Figure 2. The Hamlyn Group Color Correction Symbols

The Natural Color System (NCS) developed in Sweden (Hard and Sivik, 1981) is an attempt to apply Hering's opponent-color theory to color notation. The Hering opponent pairs of yellow-blue, red-green, and black-white, are used to identify a color. For example, a grayish-blue would be composed of blue, black, and white. A collection of 1412 color samples has been developed to provide a physical representation of the system.

Recommendations

By its very nature, the process of color specification and communication in the printing industry is rather imprecise. To help bridge the gap between the creative and manufacturing processes a number of tools have been developed. These tools and procedures can be conveniently discussed under the following headings:

1. Solid Color Specification. The use of ink-mixing types of commercial color guides represents the most efficient method of specifying solid colors.

Ideally, the guide should be printed on the substrate to be used in practice and the inks should be similar to those used in the printer's pressroom. The guides should be replaced when they become dirty or start to fade.

Verbal descriptor systems such as ISCC-NBS may be used for color specification, but in practice it would be rare to find one of these references in a printing plant. Furthermore, the ISCC-NBS system is only a way of identifying a color; how it is reproduced is left to the user.

2. Halftone Tint Specification. The overlapping halftone screen color chart is unrivalled for specifying colors that must be reproduced by combinations of the process colors. The chart should be produced under the production conditions similar to those used by a given printer. In some cases, stock color charts may be satisfactory for accurate specifications. In other cases, a custom printed color chart should be used.

   Verbal descriptor systems have the same drawbacks for halftone tint specification as they do for solid color specification.

3. Color Proof Markup. Ideally, corrections to color proofs are indicated by reference to a color chart produced under the same conditions as the proof. The desired color is indicated by marking the reference code or halftone dot percentages on the area in question. In practice, customers frequently mark corrections on proofs without reference to a color chart. There are two methods of addressing the proof markup problem. One is to play the role of "dot etcher" or "retoucher" and estimate the percentage changes in yellow, magenta, cyan, and black that are necessary in order to achieve the desired color. This is a difficult task, even for experienced dot etchers. The increasing use of GCR makes this task even more difficult. A tool such as the GATF Color Communicator is a useful aid to help visualize how changes in individual dot percentages relate to changes in

color appearance. On the other hand, overly-film types of color finders will not produce an exact simulation of the final printed color.

Another method of indicating color corrections is to state the desired change in color appearance without specifying how the change is to be achieved. The three dimensions of color may be described by the following terms:

Hue. Desired hue shifts may be indicated by using the terms redder, bluer, greener, and yellower.
Saturation. The terms cleaner or dirtier (grayer) may be used to indicate the desired position of a color relative to the neutral scale.
Lightness. The terms lighter or darker may be used to indicate decreases or increases in all the dot sizes in a given color.

The descriptors listed above are satisfactory for indicating the direction of change but they do not specify the amount of change desired. The words "slight," "moderate," and "substantial" may be used to indicate the magnitutde of change,but some misunderstanding is possible because these terms do not mean the same thing to all people. Again, the GATF Color Communicator may be a useful device to help indicate the degree to which a color should be changed.

One danger, apart from the obvious imprecision, of using verbal methods for color correction specification is their lack of constraints. For example, a customer may request more saturation in a given color area that already has maximum saturation for the in-paper-press combination in question.

Accurate color specification can only be achieved with the use of physical color samples in the form of ink mixing guides or printed color charts. These printed guides must be produced under conditions similar to those used for production at a given plant. The use of verbal descriptors will never be eliminated, but in order for them to be effective, a substantial education effort is needed. Education must start in the design and technical schools and continue through professional seminars, workshops, and publications.

It is only after all parties have a thorough understanding of the nature of color and have mastered a logical system of color description will much of the waste and frustration of vague color specification be eliminated from the color printing industry.

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Moonachie, New Jersey 07074

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(Toyo Ink Color Finder)
4014 W. Chandler Avenue
Santa Ana, California 96704

Printed Color Charts

Pantone, Inc.
55 Knickerbocker Road
Moonachie, New Jersey 07074

S.D. Scott Printing Company, Inc.
145 Hudson Street
New York, NY 10013

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4615 Forbes Avenue
Pittsburgh, Pennsylvania 15213

The Murphy Color Wheel
219 East Galena Blvd.
Aurora, Illinois 60505

Tom Norton Designs
P.O. Box 29
Cambridge, Massachusetts 02139
(The Norton Auto-Chromatic wheel is available for manufacturing under license.)

Master Color Chart Film Sets

ByChrome Co.
Box 1077
Columbus, Ohio 43216

Eastman Kodak Company
Rochester, New York 14650
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4615 Forbes Avenue
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