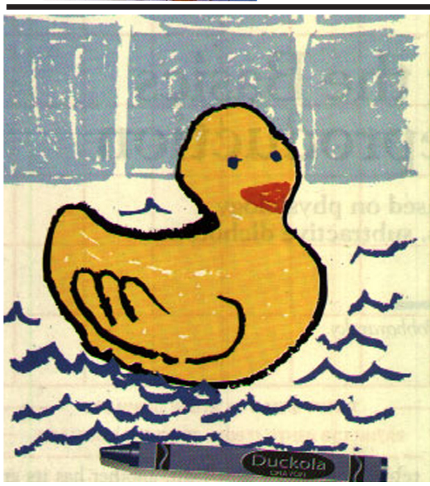
GRC 101

INTRODUCTION TO
GRAPHIC COMMUNICATIONS

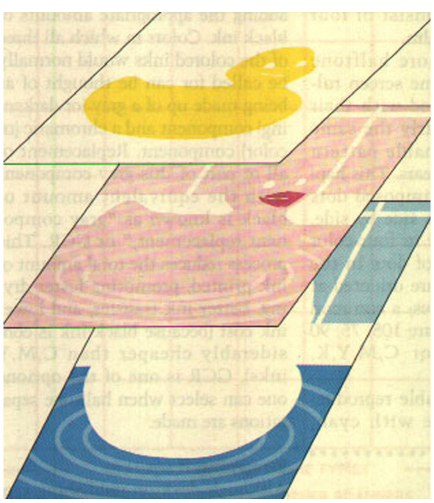
COLOR REPRODUCTION

Information Sheet No. **304**



As children, we used different crayon colors for each color in an image.

On a TV screen or computer monitor, however, the entire gamut of colors is created from a black screen by triads of red, green and blue phosphors, which vary in intensity according to the strength of the electron beam that hits them.



Unlike TV, a photo print begins with a white field made up of red, green and blue primaries at full brightness. CMY colorants in continuous tone dye layers are used to dim these RGB primaries.

A printed piece also begins with a full intensity RGB surface (as white paper). CMY and K colorants in the form of halftone dots are used to dim the paper color components as appropriate for accurate colors to be perceivedl

Desktop publishing affords extraordinary creative opportunities to a wide range of people.

But because the backgrounds of potential users vary enormously, very few fully understand the intricacies of color reproduction.

This section is designed to explain the basics of color reproduction.

Let's start with a flashback to childhood. Back then, when we drew a picture of 20 differently colored objects, we used a different crayon for each. But this intuitive approach to color is impractical for color photography, color television, computer monitors or color offset printing.

Full-color pictures reproduced by these technologies may contain thousands of colors, and we simply cannot deal with each as a unique component.

Photography, television, and printing are practical because they take advantage of a truly amazing characteristic of the eye, which is that most colors in the real world can be matched by controlling the intensities in a mixture of just three colors. This point cannot be overemphasized — it underlies all color reproduction systems and is the key to understanding how they work.

Thanks to this characteristic of the human eye, we need not use a different "crayon" for each color in a full-color reproduction — a palette of just three primary colors is sufficient. Without this enormous simplification, color television, color photography, and color printing would be not be practical.

This three-color phenomenon is rooted in physiology: there are three types of lightsensitive, cone shaped cells at the back of the eye. If you think of the eye as a camera, its "film" consists, in part, of a mosaic of 6 to 7 million of these coneshaped cells, mostly concentrated in a small, central region called the fovea. Each of the three types has its peak sensitivity at a different point in the visual spectrum. One is most sensitive to blue light, another has its greatest sensitivity to green light, and the third responds chiefly to yellow light, but with considerable sensitivity to red light as well.

When light from a colored object is imaged by the lens of the eye onto this mosaic of cells, they generate tiny voltages whose magnitudes depend upon the color of the object. These electrical signals are processed to produce the sensation of color in the brain. Although there are a number models which attempt to describe how these signals are processed to account for color vision, none is completely successful.

The eye cannot break apart a color perception into its component lights; it sees only the results of the mixture of lights.

For example, sunlight appears white to us, but Isaac Newton showed that it was composed of all colors of the rainbow when he passed sunlight through a prism.

Given the respective sensitivities of the eye's color-sensitive cells, it turns out that various mixtures of red, green, and blue lights create the widest range of perceived colors. For this reason, all color reproduction systems operate by controlling the intensities of red, green, and blue light reaching the eye from each elemental area of the picture.

While all color reproduction systems have the same aim — namely, to control RGB light intensities — how each achieves this aim is dictated by the nature of the technology and its medium.

On the screen

The screens on color televisions and computer monitors consists of a mosaic of thousands of tiny red, green, and blue phosphors arranged in groups of three, or triads. These phosphors are chemicals that emit light when struck by electrons; the color of the light depends on the specific phosphor, and the light intensity depends on the strength of the electron beam. Television receivers and computer displays adjust the light output of each phosphor to create a total picture.

The RGB phosphors are so tiny that at normal viewing distances the three lights blend together into unified colors, which vary according to the intensities of electric current striking the phosphors. In this way, color television makes use of the threecolor characteristic of the eye to simplify the production of color images. It starts off with a dark screen and uses red, green, and blue lights to form the picture.

But while printing and photography rely on the same threecolor characteristic of the eye to enable the production of color pictures, they do not start with a dark screen and add lights — they do the opposite. Photography and printing start with a white "screen" (photographic or printing paper) on which all the red, green, and blue lights are at full intensity —they start with white paper or a clear film illuminated with white light. As mentioned earlier, "white" light is composed of all the colors of the visible spectrum, naturally including red, green, and blue. To produce a color picture from this white field the individual RGB intensities must be appropriately turned down, rather than up, at each point. And you must be able to turn down the red, green, and blue lights independently — you need, in essence, separate dimmer switches for the red, green, and blue lights at each point in the picture.

These dimmer switches are provided by what we'll call "colorants," a general term covering both the dyes used in photography and the pigmented inks employed in printing. Photography and printing use a cyan (C) colorant to dim the red light, a magenta (M) colorant to dim the green light, and a yellow (Y) colorant to dim the blue light.

Printing also employs black (K) as a fourth colorant; it dims red, green, and blue light equally.

Color Photography

Color film, in its simplest form, consists of three separate, light-sensitive layers on top of each other. The first layer is sensitive to blue light, the second to green light, and the third to red light. Exposure of the film in a camera simultaneously produces a blue-light record in the top layer, a green-light record in the middle layer, and a red-light record in the bottom layer. These are records of the B, G, R light intensities of each point in the scene.

As the film is developed, the information in its blue-light record is used to form a yellow dye image. Areas in the photographed scene where blue-light intensity was low require a great deal of blue-light dimming which is achieved with a high concentration of yellow colorant. Similarly, the information in the greenlight record is used during development to generate a magenta image that correlates with the need for green-light dimming and likewise, cyan dye concentration in the bottom layer correlates with the original scene's requirements for dimming red light.

This superimposed stack of cyan, magenta, and yellow dye images controls the red, green, and blue light intensities, respectively, at each point in the photograph. The result is a fullcolor image whose colors correspond to those in the original scene.

Color photographic images are said to be "continuous tone" because dyes have no visible structure, even at moderate magnifications. There are no "pixels" of the sort that comprise a digital image.

Process-color Printing

To create a color picture by a printing process such as offset lithography, you must be able to lower the RGB intensities at any point on the paper by applying just the right amounts of cyan, magenta, and yellow inks, which dim red, green, and blue, respectively.

With printing processes it is not possible to vary ink amount on a point-by-point basis by changing the thickness of the ink layer or by altering the pigment concentration of the ink. It is possible, however, to meter out different ink amounts by printing a regular array of tiny dots whose sizes or frequency have been adjusted to cover more or less of the paper as needed. The process of making varying sized dots is called halftone printing.

In the halftone process, the same number of dots is printed per vertical and horizontal linear inch throughout—a fixed frequency— and only their relative sizes are adjusted. In this way, the dimming effect can be increased with dot size

An new all electronic alternative process which makes all dots the same size, but randomly places them—more in dark areas, less in light ones— is called Stochastic screening.

It is gaining in popularity, although, currently, it is most generally confined to upscale reproductions and special projects. Conventional halftoning is still the preferred system for most photo reproductions.

Halftone images can be created either by photographing the original picture through a screen or by digital means (using a scanner to digitize the original art, software to create halftone screens, and imagesetters to output the halftones to film). In either case, the various red, green, and blue light intensities of the original are represented by appropriately sized dots on separate pieces of film, which are then used to make printing plates.

The number of dots printed per inch — that is, the halftone screen ruling — depends upon the intended application. Halftones in newspapers can have rulings as coarse as 65 lines to the inch, while very high-quality art reproductions might have rulings as fine as 300 lines (or more) per inch. General circulation magazines, typically are printed with a 133-line ruling.

While the printing industry refers to these measurements as lines per a inch, most computer applications call them dots per inch.

The two are roughly equivalent.

To appreciate the smallness of halftone dots, consider that there are 10,000 dots in every square inch of a 100-line halftone—a 100 x 100 dot matrix occupying a 1 x 1-inch area.

The maximum area a single dot can occupy, therefore, is a square whose sides are 0.01 inch and whose area is 0.0001 square inch.

Most dots, of course, will be smaller than this, and their size is typically expressed as a percentage of the maximum size (100%). A dot occupying half of that 0.0001-square-inch area is R08/02 4 304 – Community College of Southern Nevada a 50% dot, one that covers a quarter of that area is a 25% dot, and so on. This same approach applies irrespective of screen ruling.

Printing full-color pictures with four inks is called processcolor printing and is usually done on a four-color press. Such a press is actually four separate presses aligned so that the paper passes from one to the next, picking up one ink image after another until cyan, magenta, yellow, and black ink images are superimposed in exact register.

Each press station prints one of the four "process" inks (cyan, magenta, yellow, and black), and each unit requires a separate printing plate. The halftone image on the printing plate defines how much ink should be printed at each point in the image.

Ink amount is encoded in terms of dot size. As the need for separate printing plates implies, the original color picture must be "separated" into four halftone records before plates can be made. These C, M, Y, K records are called color separations and consist of four halftone images on film. Each individual film is properly referred to as a "Color Printer".

When two or more halftone images with the same screen ruling are superimposed with their lines of dots at nearly the same angle, an objectionable pattern called a "moiré" appears.

This happens because superimposed dots are lighter than dots side by side. To minimize moiré in four-color printing, the lines of dots in the C, M, Y, K halftones are oriented at different screen angles; a common set of screen angles are 105, 75, 90 and 45 degrees for C, M, Y, K, respectively.

Although reasonable reproductions can be made with cyan, magenta, and yellow inks, image quality can be improved by also printing appropriate amounts of black ink. Printing black ink in the shadows makes them darker, thereby extending the tonal range and making it possible to increase contrast in dark colors so that more details are visible in the shadows. It can also improve the colorfulness (saturation) of dark colors.

Since black ink reduces the R, G, B light intensities equally, it can replace the C, M, Y inks in picture locations where all three inks would print. In those areas of the picture, the same final color can be achieved by printing less cyan, less magenta and less yellow and adding the appropriate amounts of black ink.

Colors in which all three of the colored inks would normally be called for can be thought of as being made up of a gray (or darkening) component and a chromatic (or color) component.

Replacement of all or part of this gray component with the equivalent amount of black is known as "gray component replacement," or GCR. This process reduces the total amount of ink printed, promoting faster drying, better ink transfer, and lower ink cost (because black ink is considerably cheaper than C, M, Y inks).

GCR is one of the options one can select when halftone color separations are made.

Wrapping it up

Although desktop publishing represents a major step in the democratization of access, the same color reproduction fundamentals apply as in traditional publishing. What once could be done only on capital-intensive equipment by highly trained specialists can, in theory, now be done by a nonspecialist with relatively inexpensive equipment.

We have (in some cases) moved full color from being a "novelty" to being a "commodity".

In the hands of some individuals, desktop-published color reproductions can rival the quality produced by specialists using high-end equipment. We are only in the beginning stages of the color desktop revolution.

Software developers are writing even more sophisticated programs incorporating more and more expert knowledge. As these more intelligent programs come on line, the door opens ever wider, affording an increasing number of people extra ordinary creative opportunities for expression.

Color management One of the biggest challenges facing the desktop environment is the succcessful communication of color information between different color gamuts, equipment and systems.

The downside is that because there are sometimes vast disparities which can occur from what is created (on the screen) with RGB to what comes off of the proofing device or printing press (CMYK)

The industry has been working diligently to develop methods of communicating andcontrolling color.

A number methods have been developed, from inexpensive visual matching tools to expensive technolgical marvels which require special and expensive monitors and equipment profiling.

A total answer may never been reached but, increasingly, the difficulties are being addressed, mostly by using international color standards to which many manufacturers now design products and supplies.

Until the technology of desktop publishing rivals the ease of use of office copiers, however, skill and fundamental understanding will be needed by users if they are to begin to realize the full potential of this new approach to image reproduction.