# Imbibition Release Prints Utilizing Digital Technology

By Edward Delvers, Bruce Richardson, and Thomas White

*Motion-picture prints made with the dye transfer, or imbibition (IB), process have a reputation for superior image quality and permanence. The process offers unique control over the dynamic range and color gamut of the prints. The insertion of a digital link in the traditional path of the image between the camera and the dye transfer print simplifies the chemistry of the process and makes it possible to manufacture dye prints as a theatrical release medium for images originated either electronically or on film.*

Some of the first color motion-picture prints were made by depositing dyes on black-and-white film, tinting individual frames by hand. Later, many alternative dye chemistries and mechanical methods of application were tried by the industry. In the 1930s, the dye transfer or imbibition (IB) process, whereby three dyes are printed onto blank film to form the image, emerged as the predominant technology in color motion-picture printing. IB was eventually displaced in the 1970s by the process of color-coupled development, in which dye precursors incorporated into the film during manufacture are put through various reactions during the development process to yield dye images directly in place.

## Dye Transfer Process

In the dye transfer process, a color image is formed when cyan, magenta, and yellow dyes are transferred to blank stock from three different black-and-white positive separations made on matrix film. The image on matrix film exists in the form of a gelatin relief, consisting of a 3-D topography of hills and valleys proportional to image density. During the printing procedure, each matrix is soaked in dye, rinsed to remove surface concentrations, and brought into registered contact with a mordanted blank. The dye diffuses from the matrix into the blank to form a positive image; a color picture appears after the third dye is transferred. In motion-picture prints, the soundtrack and other coding marks can either be printed with dye or printed separately as a silver record.

## Advantages

Dye transfer prints have always been held in high regard in both the motion-picture and still photography fields for their dynamic range, color saturation, and archival nature. Some of these advantages, when compared to those of color-coupled film, are inherent in the materials and processing used to make a dye print. A dye transfer print can theoretically have a minimum density of the clear blank stock, and the maximum density can reach values of 5.0 from the high concentrations of dye that can be transferred.

Dye transfer printing also offers the ability to alter the color gamut of the reproduction by using different dye combinations, an option not present in color-coupled film printing. This is especially applicable in the treatment of color as a special effect and for animation. The advantage of the permanence of dye prints is due in part to the stability of the dyes themselves, as well as in part to the simpler processes of dye transfer that leave few residual chemicals in the print.

## Work in Progress

Chromax is in the process of engineering a dye transfer printing system that exploits the inherent advantages of the process by applying recent developments in technology. Of particular interest is the use of digital imaging to control color rendition. Modern materials and precision machining help maintain the accuracy and consistency needed for registration and transfer procedures.

The research is organized around matrix film, development, blank stock, mordant, dyes, transfer chemistry, and transfer equipment. This paper describes the characteristics of each of these materials and processes and the tests that have been conducted with digital imaging. A system using other options — such as different classes of dyes, alternative solvents, polymer emulsions, different matrix configurations, or other transfer mechanics — could also be engineered around the results of these tests.

## Matrix Film

The matrix film used in dye transfer needs to have a fine grain structure, strong subbing, stable base material, and gelatin with proper mechanical and hardening characteristics. Panchromatic, orthochromatic, or blue-sensitive emulsions can be formulated, but they generally contain a blocking dye designed to limit the penetration of the exposing light through the film thickness.

During the exposure of matrix film, which is made through the base, the dye absorbs extraneous light and confines the latent image in the emulsion layer adjacent to the film substrate. Subsequent processing yields a relief image in gelatin that is attached to the base. This relief image must withstand repeated thermal cycling, mechanical pressure, abrasion, drying, wetting, and chemical cleaning, and yet still be resilient, sharp, and able to repeatedly absorb and release dye.

Initial tests were conducted with Kodak 4150 matrix film, a blue-sensitive emulsion on polyester base made for the Kodak dye transfer paper print system. Sheet stock was slit and perforated to motion-picture standards and

---

Presented at the 136th SMPTE Technical Conference and World Media Expo in Los Angeles (paper no. 136-60) on October 14, 1994. Edward Delvers and Bruce Richardson (who co-presented the paper), and Thomas White are with Chromax, Inc., Santa Barbara, CA 93101.

spliced to provide film strips. This film, though not manufactured for motion-picture use, was adequate for the purpose of these tests.

### Development

Tanning development, designed specifically to generate the relief image in matrix film, uses the ability of certain developers to harden gelatin imagewise. During processing, the oxidized developer reacts to crosslink gelatin in the vicinity of the developed silver grain. This renders the gelatin harder and less soluble than that of the unexposed, undeveloped areas of the emulsion. The unhardened and more soluble gelatin is removed by hot water in the final processing step, leaving behind the relief image.

The matrix developer is important in determining the characteristic curve of the whole system because tanning developers determine the gelatin's thickness, sharpness, and hardness, all of which influence the transferred image. As in other black-and-white processing, the developer also determines highlight and shadow detail, sharpness, grain, granularity, and contrast.

### Blank Film and Mordants

The blank film — in which the image is formed by dyes that diffuse into it during transfer — must have the ability to attract and retain dye. Gelatin emulsions have some inherent dye affinity, but not enough to prevent the diffusion of dye sideways within the blank after the transfer. The addition of mordants to the emulsion increases the dye affinity of the blank and improves the resolution of the transferred image.

Mordants are chemical structures either contained within or bonded to the emulsion of the blank that attract and anchor dye molecules. They directly affect the transfer rate and dye density. The mordant research conducted at Chromax has ranged from metallic salts to polymers, both applied by aftertreatment and incorporated in the stock at manufacture.

Tests were conducted using fixed-out, black-and-white, polyester-base stock, including Agfa 561 and Kodak SO-202, both aftertreated with mordants. Chromax's own stock was coated with mordants incorporated directly in the blank.

### Dyes

A desirable dye system consists of water-based chemistry with compatible dyes that will transfer and remain sharp. The dyes need good spectral absorption, mordant compatibility, good transfer characteristics, color fastness during projection, and stability in storage. Single-component dye solutions represent the simplest chemistry, although sometimes mixtures are beneficial.

In all cases, dyes have overlapping spectral absorptions, and some form of color correction is desirable. In dye transfer printing, the usual photomechanical technique of color correction with color masking involves a tedious procedure with registered contrast masks and intermediate negatives. Another technique of color correction unique to dye transfer is the alteration of the dye solutions to change the color rendition. This does not provide color masking by compensating for unwanted absorptions in the dyes; however, it can be used to provide some correction when the use of contrast masks in printing is impractical. In fact, this ability to alter the color gamut of the image is one of the advantages of the dye transfer process.

For testing purposes, single-component solutions of anionic dyes were used. These are of the type commercially classified as acid and direct dyes, traditionally used in dye printing and supported by a wealth of research from the textile and printing industries. In addition to the colors available commercially, dyes can be synthesized for specific spectral and transfer characteristics.

### Digital Imaging

Digital imaging incorporated into a dye transfer process serves two purposes. First, it allows the convenient application of color correction and color control when printing from film originals of all kinds. It offers an unprecedented ability to apply color masking corrections directly during matrix exposure. With the color display technology available today, it is possible to represent the visual effects of color corrections and dye substitutions on a viewing screen before the matrix is generated.

Second, it is a means of producing motion-picture prints directly from digital files originated in electronic cameras or computers without going through the conventional film intermediate stage. Electronically composed images can be output to film without the constraints of materials specifically designed to reproduce images originated on camera negative film. The color gamut is not limited to the range that can be created with the cyan, magenta, and yellow dyes manufactured into dye-coupled film stocks.

Two approaches to generating matrix film images with digitally applied corrections were taken. The first (Fig. 1) is the direct exposure of matrix film with a digital output device such as a film recorder. The chart shows that the imaging computer can accept original image data from negative or positive film originals, black-and-white color separations, computer-generated imaging (CGI) files, or high-definition television (HDTV). This information is processed to match the reproduction characteristics of the dye transfer system and output through a film recorder onto three separate matrix films. These matrix films are then used to print multiple release print copies.

The imaging computer incorporates the corrections needed to account for the characteristics of the originating medium (such as color timing), the image itself (image contrast and creative effects), and the dye transfer system (including matrix sensitometry and development, dye chemistry, mordanted blank, and transfer conditions). At this stage it is possible to previsualize the effect of these corrections on the image and verify the color gamut available from substitute dye sets on a color monitor.

Among film recorders, cathode ray tube (CRT) devices widely used in the industry can expose matrix film successfully at a slow rate and with multiple scans as necessary. Long exposures can produce sharp pictures within their limits of operation. Laser film recorders can expose matrix film much more quickly. Another film recording technology, electron beam recording (EBR), is not applicable to direct

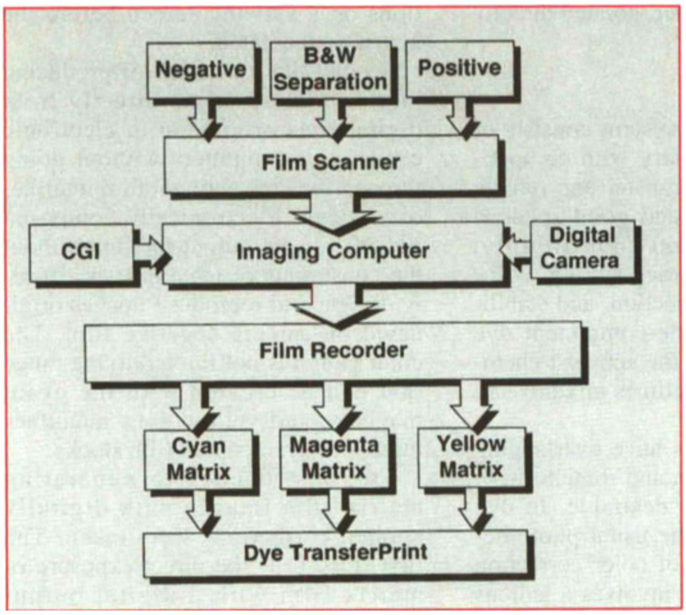

*Figure 1. Direct matrix film exposure.*

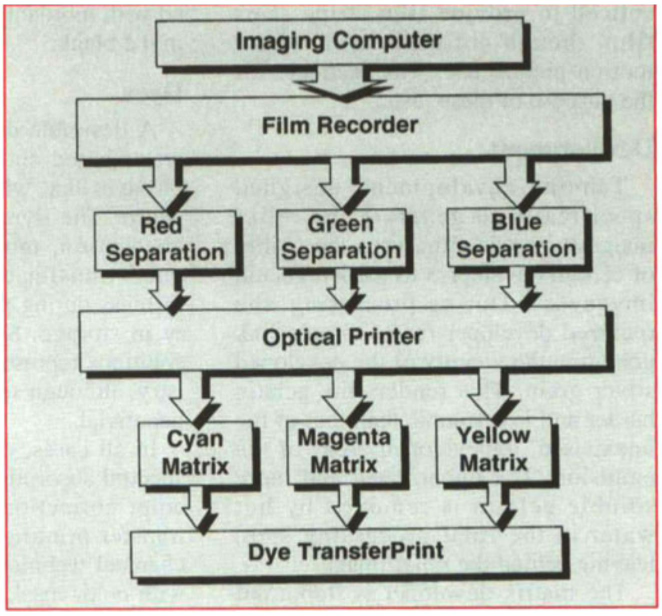

*Figure 2. Matrix film from digital separation masters.*

matrix film exposure because the beam is absorbed by the base during exposure. In all of these cases, the film recorder outputs to the matrix film in the final format of the release print, from 4-perf 35mm to 15-perf 70mm.

The second method (Fig. 2) is the two-stage insertion of a digital processing step through the creation of digitally corrected and mastered separation negatives for printing matrix films optically. The chart shows the imaging computer (still being input from the same five possible sources in Fig. 1) that outputs through a film recorder, but in this case onto suitable black-and-white stock instead of matrix film. (EBR film recording technology is applicable to this step, as are CRTs and lasers.) The separation master set is then used to expose the matrix film of the dye transfer system. The digital corrections incorporate the characteristics of the matrix film, the separation film, and contrast variations of the duplication step. Some generation loss is associated with this technique, yet it has the advantage of resulting in a printing master for duplicate matrix sets. By optical printing, matrix film can be exposed in a variety of formats (35mm to 70mm) from one original separation set.

## Transfer Mechanism

Once the matrix films are made, the successful printing of images depends on accurate mechanical processes, including registration of matrix and blank, the contact procedure, and the regulation of temperature and pressure during transfer. Chemical conditions of the matrix and blank films, pretreatment of blank, dye concentration, and properties of the mordant all affect the transfer characteristics. Although these conditions can be varied to control the image reproduction, it is now possible and preferable to optimize and standardize the procedure, thus controlling the characteristics of the final image by applying the corrections in the matrix exposure.

The test transfers were made manually on a thermostatically controlled register board that accommodates 35, 65, and 70mm film segments with interchangeable pin strips in a variety of perforations and pitches. The registration takes place on full-fit pins in every perforation on one edge of the film and on traveling pins on the opposite edge. The pin strips are machined for a total cumulative error of 0.0015 in. (0.04 mm) over the film length of 24 in. (61 cm).

## Conclusion

In dye transfer printing, a digital interface makes possible a standardization of processing providing a way of previsualizing the color gamut. It also provides an output capability for electronically originated images that bypass any color intermediate stage. At Chromax, experiments with exposing matrix film using digital imaging techniques have determined that it is possible to electronically (instead of optically and chemically) control color balance. Additionally, the digital link in the imaging process makes image enhancement and manipulation techniques available in a dye transfer system with a flexibility and performance never before possible.

## Acknowledgments

We thank our many friends who have cooperated with us in these tests by providing expertise, materials, and encouragement: Jonathan Erland, Technology Council of the Motion Picture and Television Industry; Michael Friend, Academy of Motion Picture Arts and Sciences; Mike Boudry, Computer Film Co.; John Baptista, CFI; John Galt and Ed Armstrong, Sony Pictures High Definition Center; Glenn Kennel, Eastman Kodak Co.; Bruno George, Rhythm and Hues Studios; Ray Feeney and Paul Miller, RFX, Inc.; Phil Feiner, Pacific Title Co.; David DiFrancesco, Pixar; Paul Bourque, Agfa Div. of Bayer Corp.; Mac Jibiki, Fuji Photo Film USA; and many dye suppliers.