Eastman Color Print Film 5384

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Eastman color print film 5384/7384 combines the benefits of process ECP-2 (with shortened processing wet time), significantly improved dark-keeping dye stability, and reduced sensitivity to process variations. The new film is designed to replace all formats of Eastman color SP print film 5383/7383 and Eastman color LFSP print film 7379 currently available. The sensitometric characteristics, image structure, color rendition, and performance of the new film are discussed.

The history of Eastman color print film over the past 30 years parallels the development of emulsion and processing technology. The first Eastman color print film was introduced in 1950 by Dr. W. T. Hanson, Jr., of Kodak Research Laboratories.[1] It was designated process ECP, and had a processing temperature of 70°F and a processing wet time of 45 minutes. This was followed by a 75°F/28-min cycle in 1966 and an 80°F/20-min cycle in 1967.

As the use of print film increased in all formats, there was a need for faster access times. As a result, Eastman color SP print film 5383/7383 and process ECP-2 were introduced in 1974,[2] featuring a significant reduction in processing wet time compared to process ECP: 10 minutes at 98°F. In addition, process ECP-2 provided advantages in several other areas. These advantages included environmental considerations, in that less water was discharged with lower levels of COD and BOD, and lower chemical and energy costs. In addition, productivity was increased by allowing faster machine speeds in a conversion from process ECP, and considerable reduction in capital costs and floor-space requirements were possible for new processing-machine installations.

In 1978 at the 120th SMPTE Technical Conference in New York City, "Two New Eastman Color Print Films with Improved Cyan Dye Dark-Keeping Stability" were announced.[3] These films, Eastman color LF print film 7378 for process ECP and Eastman Color LFSP print film 7379 for process ECP-2, provided greatly improved dark-keeping cyan dye stability, the dye layer that faded first in previous print films. These films exhibit more than a 10-fold increase in cyan dark-keeping dye stability and have been well received by those users to whom this is an important consideration.

The introduction of Eastman color print film 5384/7384 is a result of the desire to make the advantages of new print film technology available. The new film provides the combined benefits of process ECP-2, the above "LF" films, and reduced sensitivity to process variations. Accompanying the new film are some slight modifications to process ECP-2, which will now be called process ECP-2A.

Key Features

Dye Stability

Eastman color print film 5384/7384 features a significant improvement in dark-keeping dye stability in both the cyan and yellow layers compared to 5383/7383. The improved cyan dark-keeping dye stability is a result of the substitution of a more stable cyan dye-forming coupler.

The primary dark-keeping fade reaction of the cyan dye is the reduction to a colorless leuco dye induced by the residual coupler in the film[4] (Fig. 1). Any of a number of other reductants can be present to induce the fading reaction, such as residual hypo from the fixer or the incorporated interlayer scavengers in the film. The dye present in the new film is much less susceptible to these kinds of reactions, which accounts for its better dark-keeping stability.

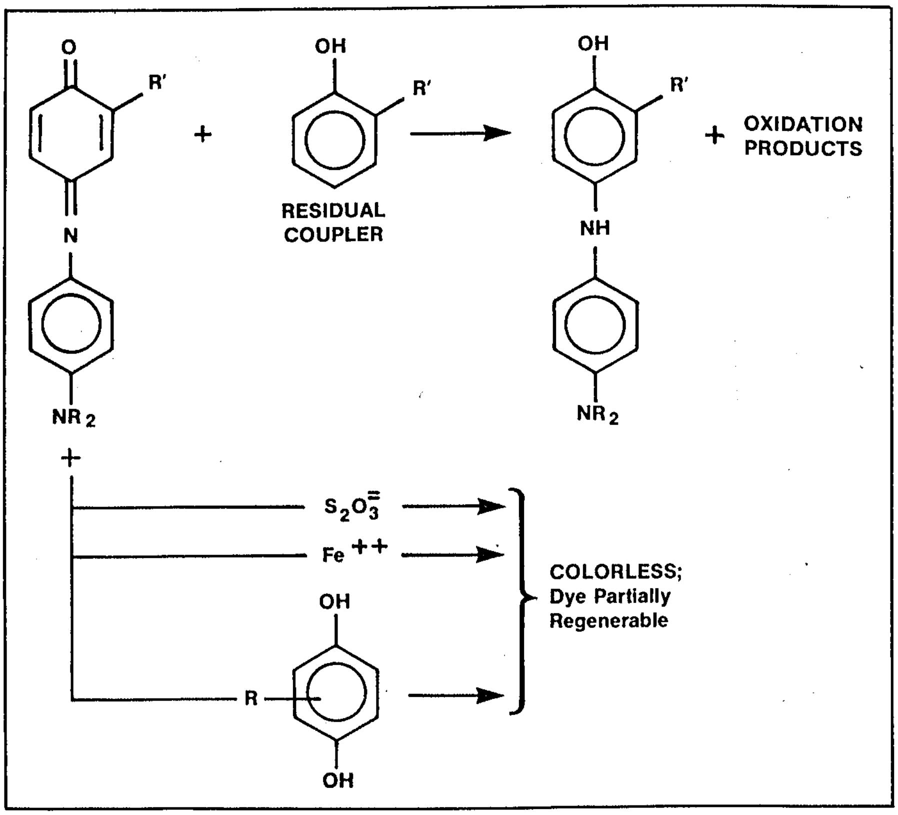

Figure 1. Primary dark-keeping fade reaction of a cyan dye.

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The 5384 also incorporates a new yellow dye-forming coupler, which helps improve the dark-keeping stability of the yellow dye. The test procedure Kodak uses to predict color dye stability[5] under standardized dark-keeping conditions consists of incubating processed sensitometric strips at several elevated temperatures at a constant 40% relative humidity. Density measurements of each dye layer are then conducted at specific intervals.

The actual data from the accelerated tests at elevated temperatures is used to generate a series of curves of each dye layer, as is shown in Fig. 2. The solid lines show the actual density losses at elevated temperatures from an original density of 1.0.

Using actual accelerated test data, a computer program then uses the Arrhenius equation[6] to predict dye stability at temperatures of 24°C and lower. This equation is:

$$k = Ae^{-E_a/RT}$$

where k is a rate constant, A is the frequency factor, E_a is the activation energy of the reaction, R is the universal gas constant, and T is the absolute temperature (°K).

The Arrhenius equation describes the rate of a chemical reaction (in this case the destruction of a dye) as a function of temperature. By integrating both sides of the equation, we find that the logarithm of the rate of dye fade will produce a straight line when plotted against the reciprocal of the absolute temperature. This analysis allows the prediction of stability curves for each dye layer under room-temperature keeping conditions (24°C), as is shown by the dotted lines in Fig. 2.*

In addition to dye stability predictions at room-temperature keeping conditions, the Arrhenius equation can also be used to predict long-term dye changes that can be expected with low-temperature dark storage. Figure 3* shows the predictions for storage of Eastman color print film 5384/7384 at room temperature (24°C), typical storage vault temperature (15°C), refrigerator temperature (7°C), and freezer temperatures of −8°C and −18°C. This plot is given on a linear scale for the dye showing the most change, which, in the case of 5384/

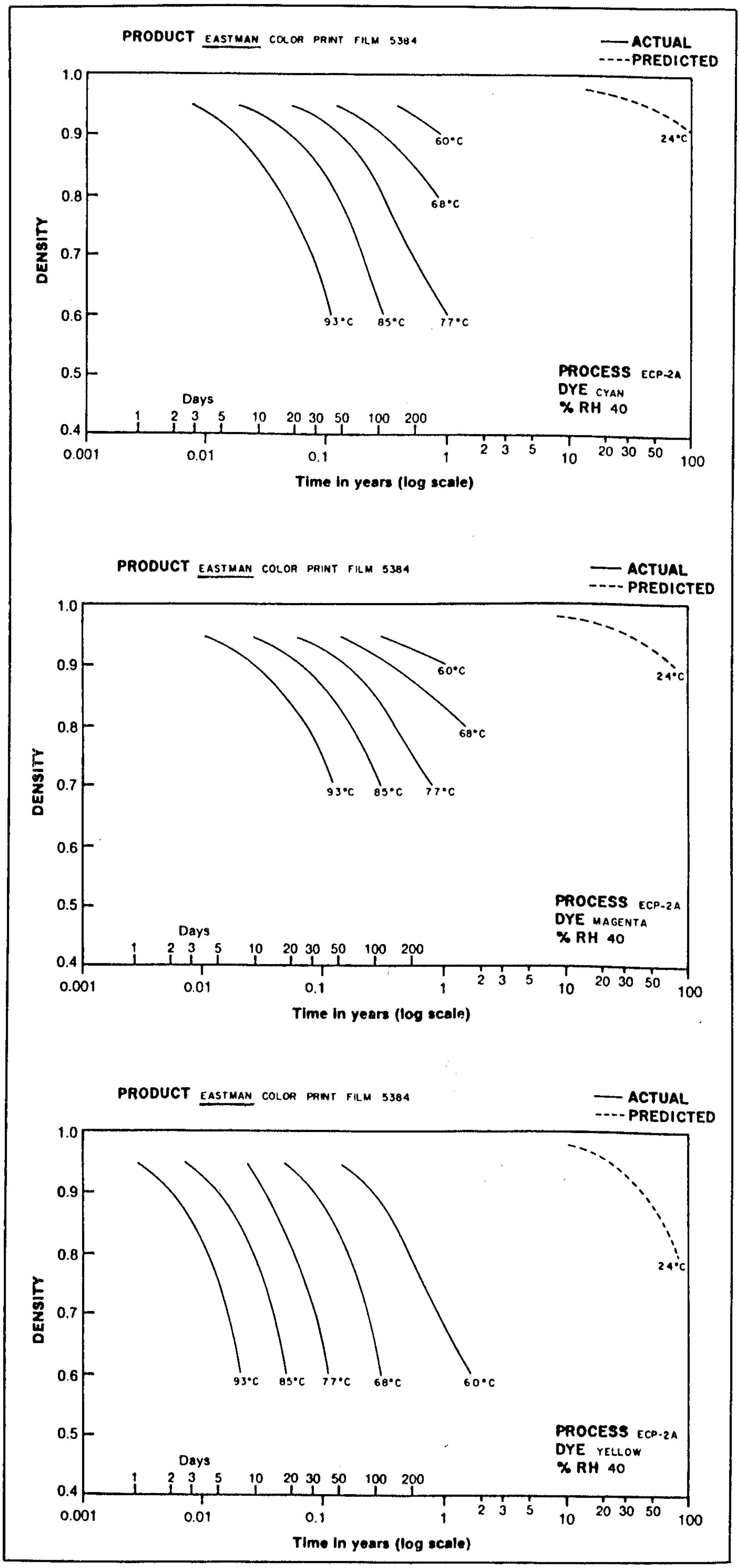

Figure 2. Dark-fading of image dyes at different temperatures from an original density of 1.0.

* Dye stability data on Eastman color films will be updated periodically; before using these data to determine the proper storage conditions for your processed films, check to make sure that the information you have is up-to-date.

7384, is the yellow dye.

The improved cyan and yellow dark-keeping dye stability results in a dramatic improvement in overall print dark-keeping dye stability for 5384 film relative to that for 5383 film. Further, storage at lower temperatures, such as 15°C and lower, should increase the useful life of the film by a factor of approximately five times or more.

Reduced Process Sensitivity

A recent international survey of laboratories processing Eastman color SP print film 5383 in process ECP-2 demonstrated that the most significant laboratory-to-laboratory sensitometric variation was in the upper-scale contrast of the blue-sensitive layer. The emulsion technology incorporated in the new film (5384) results in the blue-sensitive layer being much less sensitive to process variations. As shown in Fig. 4, the variation in blue upper-scale contrast is much smaller for 5384 film; it is approximately half that of Eastman color SP film 5383. The slight contrast changes that occur are similar for all three layers in the new film. As a consequence, 5384 has less contrast and/or speed mismatch with process variations than with previous color print films. This change will significantly reduce the contrast variation from laboratory to laboratory, and also within any given laboratory on a day-to-day basis.

Film Structure

Eastman color print film 5384 has a conventional color print film structure, as shown in Fig. 5. The film is topped with a protective gel overcoat containing matte and lubricants to facilitate film transport, handling, and printing properties. The red-, green-, and blue-sensitive layers have interlayers between them to help prevent color contamination that could adversely affect picture quality. Red and green absorbing dyes are also present in the film to reduce light-scattering throughout the layers, thus increasing the sharpness of the dye images.

Eastman color print film 5384 features the use of new emulsion technology in the blue-sensitive layer. This new emulsion develops more rapidly than the 5383 yellow emulsion and can be coated in a thinner layer, as is shown in Fig. 5. This technology helps provide the reduced process sensitivity of 5384 and also has an impact on color reproduction and printing.

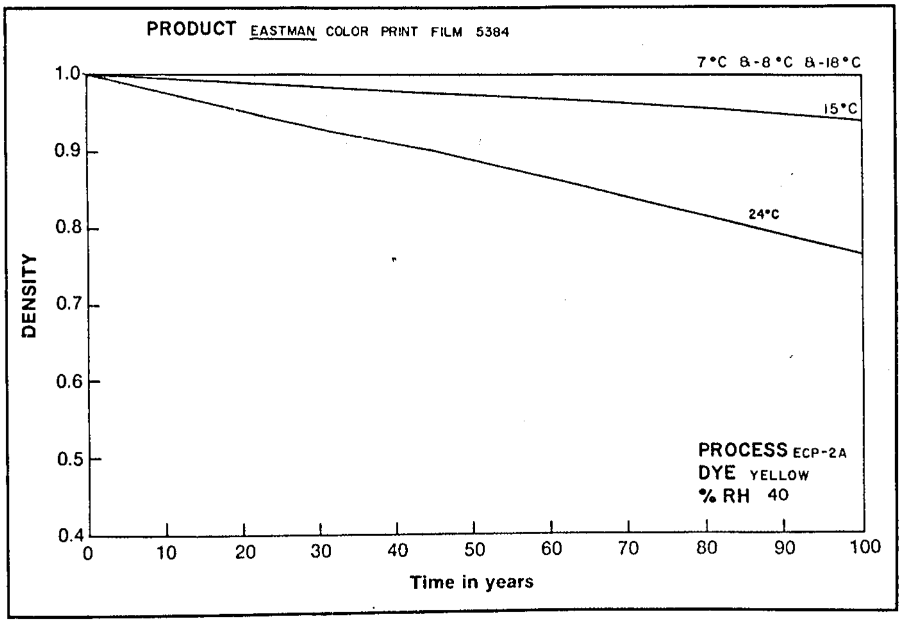

Figure 3. Plot of long-term dye changes that can be expected with low-temperature dark storage (linear scale).

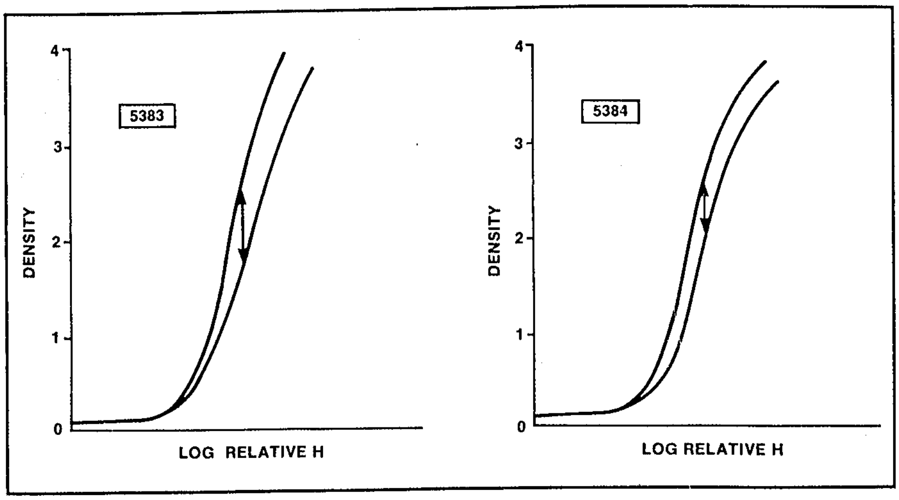

Figure 4. Blue contrast variations from laboratory survey.

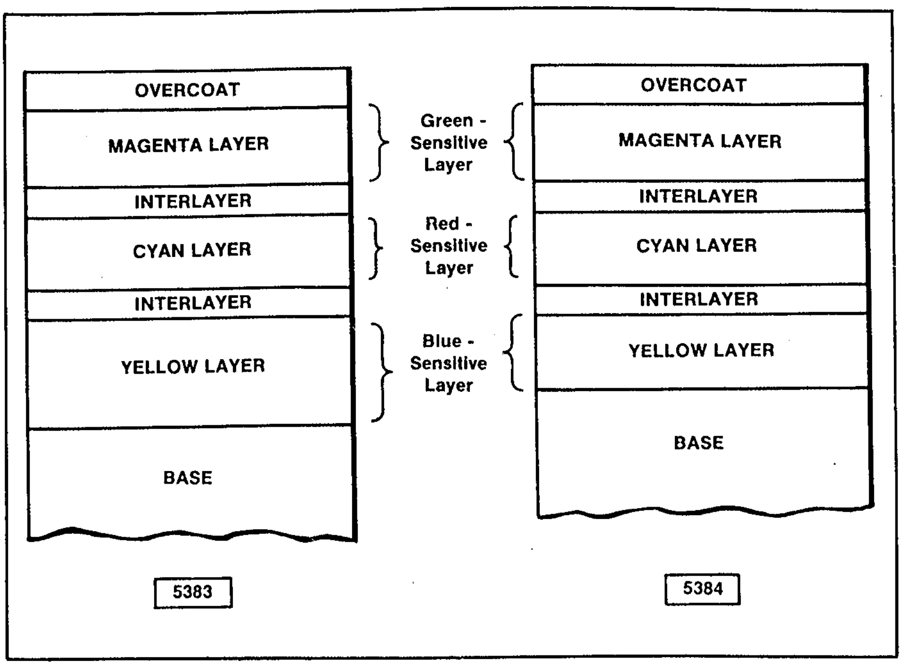

Figure 5. Structure of Eastman color print films.

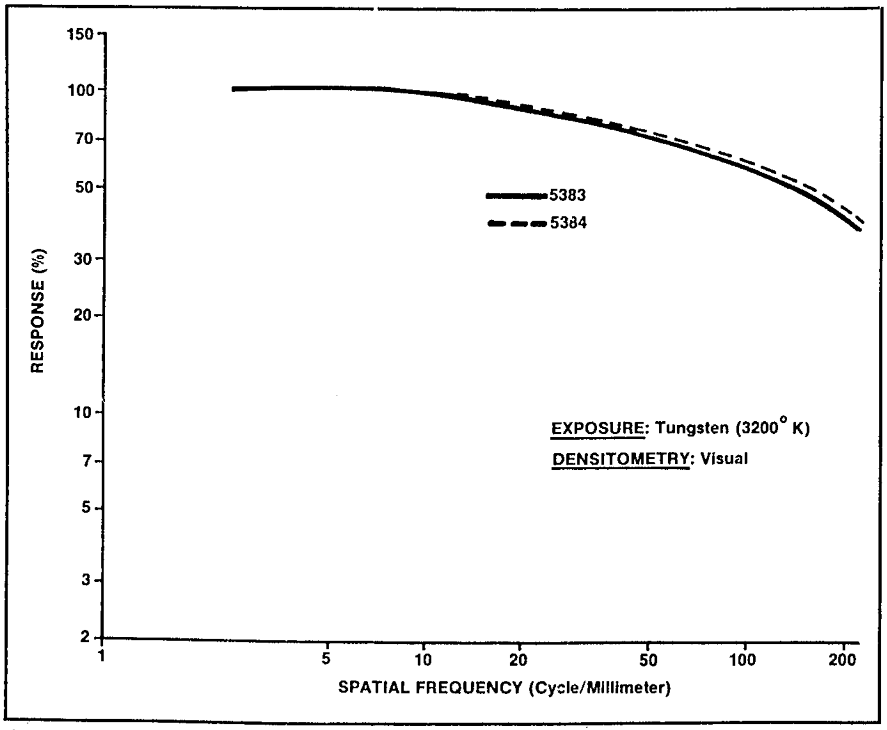

Figure 6. Modulation transfer function (MTF) of Eastman color print films.

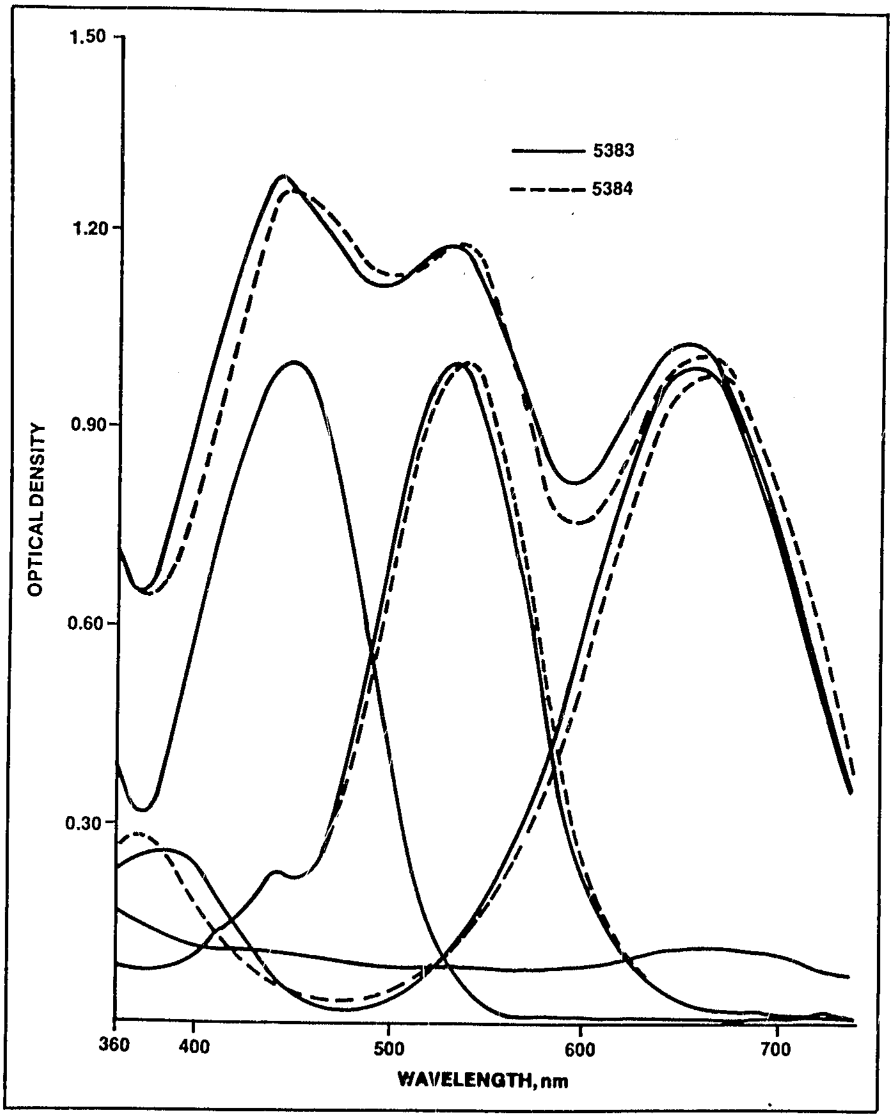

Figure 7. Spectral dye density of image-forming dyes.

Basic Film Characteristics

Image Structure

The granularity and sharpness of 5384 are similar to those for Eastman color SP print film 5383. Data on granularity, resolving power, and sharpness are given in Tables 1 and 2 and Fig. 6, respectively.

Color Reproduction

The 5384 is designed to provide the same excellent tone and color reproduction characteristics as Eastman color SP print film 5383. Tone and color reproduction of a color print film are primarily dependent on three parameters:

1. Spectral dye density of the image-forming dyes,
2. Neutral tonal scale sensitometric response, and
3. Spectral sensitivity.

In order to provide the optimum color reproduction, all of these parameters must be balanced to produce the desired results.

Spectral Dye Density

The spectral dye density of 5384 is illustrated in Fig. 7. As indicated, the dye curves are similar to those of Eastman color SP print film 5383 expect for the cyan dye, which peaks at a slightly longer wavelength.

Neutral Tonal Scale Sensitometric Response

The neutral scale sensitometric responses of 5384 and 5383 are similar except for some small differences in the red and blue characteristic curves (Fig. 8). The 5384 has slightly faster blue speed than 5383 in order to

Table 1 — Granularity of Eastman Color Print Films

Diffuse RMS Granularity*	
5384	5383
6.0	6.0

* Read at a net diffuse visual density of 1.0 using a 48-μm aperture.

Table 2 — Resolving Power of Eastman Color Print Films

	T.O.C.	T.O.C.
Lines per mm	1.6:1	1000:1
5383	250	500
5384	250	630

achieve the same "effective" printing speed. The increased blue speed is needed because of a blue spectral sensitivity difference, which is discussed further in the next section. The 5384 blue maximum density (D-max) is also somewhat lower than 5383. This difference in density, however, is at a level that exceeds the density found in typical scenes and, therefore, does not affect picture quality. The 5384 red characteristic curve has a slightly different contrast to compensate for the slightly shifted cyan spectral dye density.

Spectral Sensitivity

The spectral sensitivities of 5384 film are given in Fig. 9. As indicated, the blue spectral sensitivity of 5384 is shifted to a longer wavelength than that of 5383.

This difference can be seen more readily by looking at the spectral response of the print film. The spectral response takes into account the print film spectral sensitivity as well as the characteristics of the printer illuminant, any filters used in the beam, and the spectral dye density of processed negative film stock. Spectral response is defined as follows:

$$S_{eff}(\lambda) = S(\lambda)Ep(\lambda)F(\lambda)T_N(\lambda)$$

where $S_{eff}(\lambda)$ is the spectral response at wavelength λ, $S(\lambda)$ is the raw-stock spectral sensitivity of the print film, $Ep(\lambda)$ is the spectral characteristic of the printer light source, $F(\lambda)$ is the transmittance of the UV printing filter, and $T_N(\lambda)$ is the transmittance of the D-min of processed negative film.

As indicated in Fig. 10, the blue spectral response of 5384 is shifted approximately 30 to 35 nm in a longer wavelength direction. As a result of this change, there are some slight color reproduction differences in 5384 compared to 5383. A plot of some of these differences is given in Fig. 11.

Sensitometric (Raw-stock Speed) vs Printer Speed

The raw-stock blue speed of 5384 (that is, the speed measured when using a silver step tablet exposure) is slightly faster than 5383 in order to give the same "printing" speed (that is, printer trim settings) when negative films are printed. This blue speed difference is necessary because the blue spectral sensitivity of 5384 "sees" slightly higher blue density in negative films than 5383. If this difference were not compensated for in raw-stock

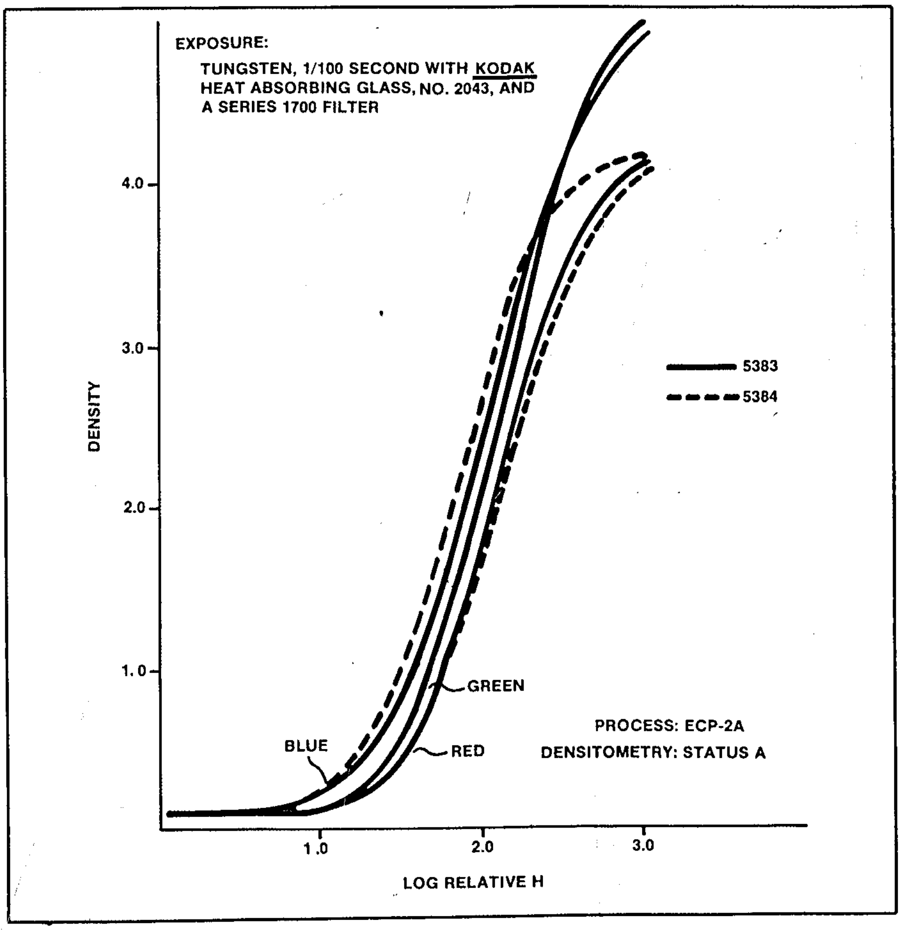

Figure 8. Sensitometric comparison of 5384 and 5383.

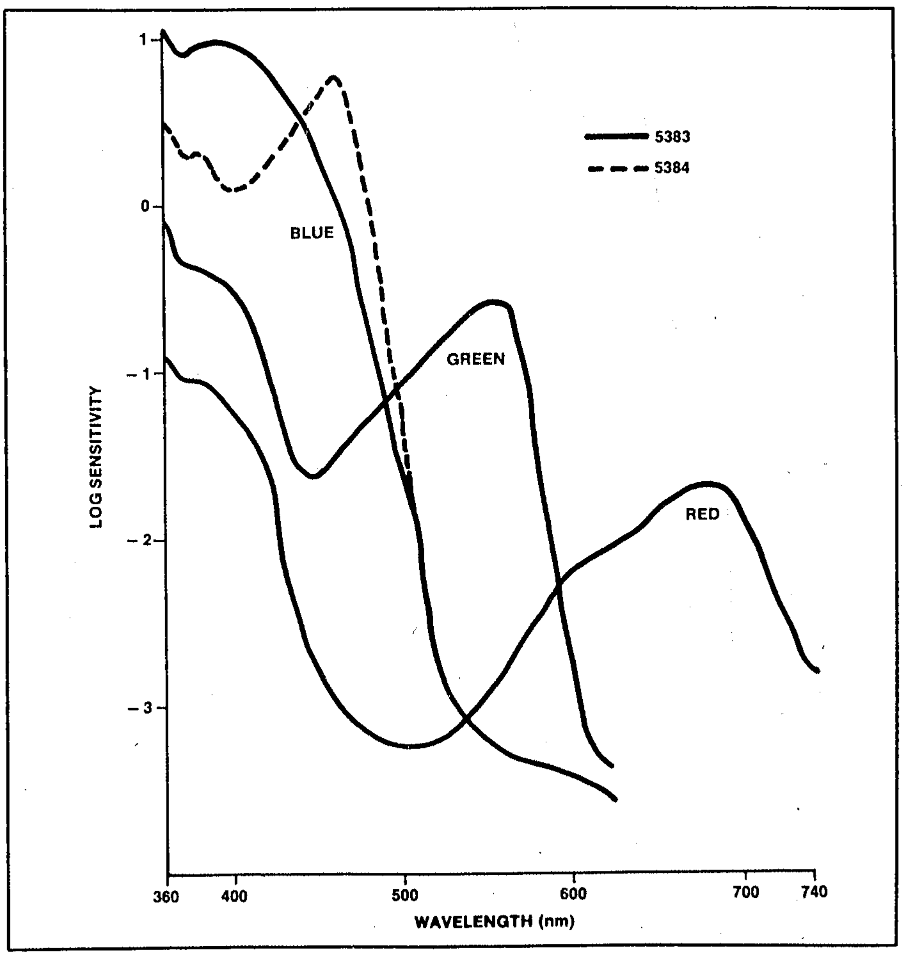

Figure 9. Spectral sensitivity of Eastman color print films.

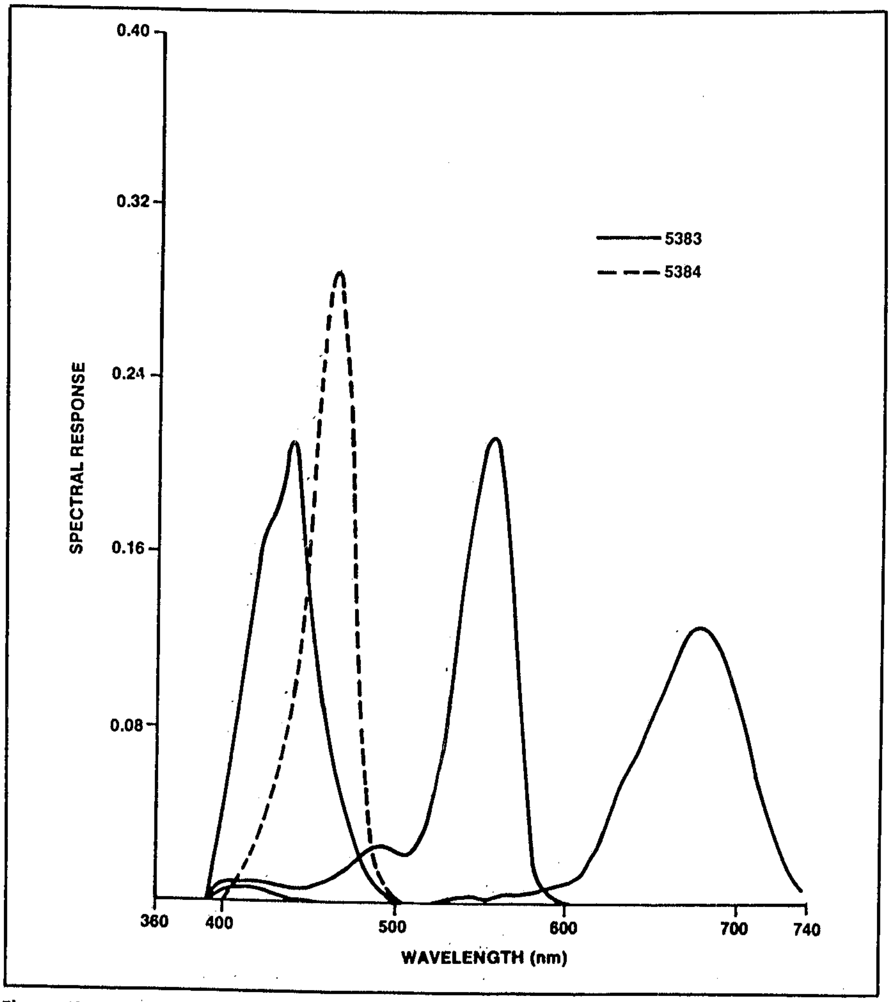

Figure 10. Spectral response of Eastman color print films (includes spectral sensitivity, printer light source, 2B printing filter, and Eastman color negative II film 5247 D-min).

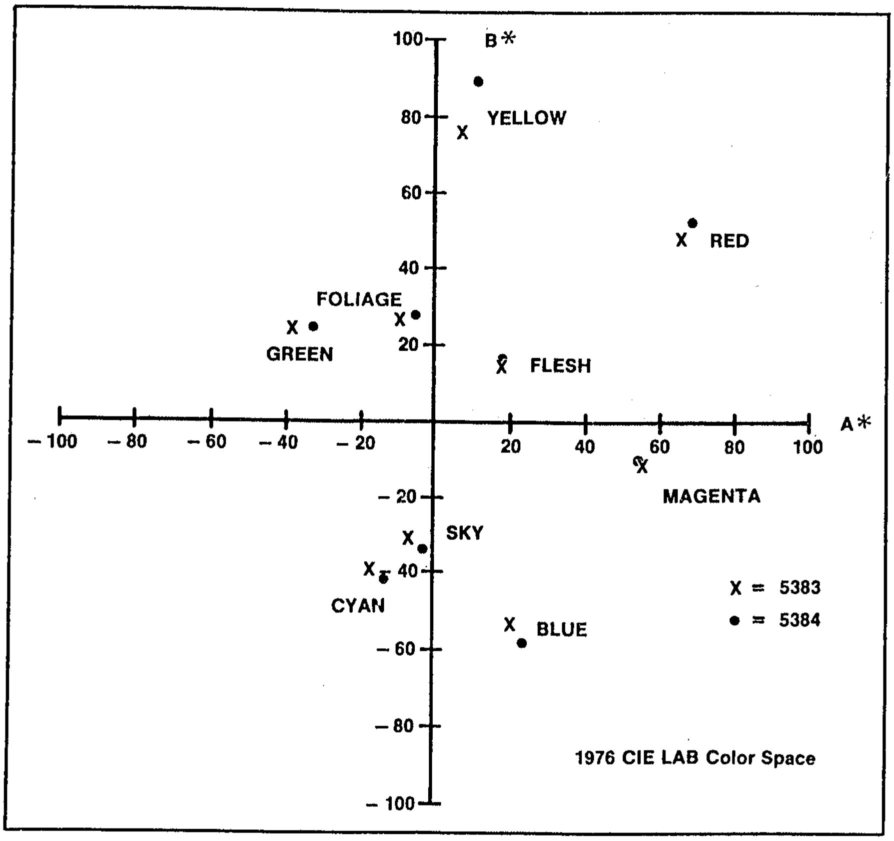

Figure 11. Color reproduction of Eastman color print films.

speed, more blue exposure would be required in the printer (approximately two to three lights) in order to produce the same blue density in the final print.

Intercut Timing

The blue spectral sensitivity of 5384 has an impact on intercut timing that should be beneficial in allowing answer prints and release prints to be more nearly alike in color balance without the use of correction factors in making intermediates. This is because 5384 "sees" all negative yellow dyes alike, whereas 5383 sees more differences between dyes (such as between 5247 and 5249, as illustrated in Fig. 12).

The color differences in an intercut roll are, of course, timed out when making an answer print on 5383, for example. However, when intermediates are made using the answer print tape, correction factors are sometimes applied (particularly with the 5249 section) so that the release prints from the duplicate negative can be one-light printed. These corrections are normally in the yellow/blue direction. If corrections are not made prior to making the intermediates, the color balance of the 5249 sections on the release print tends to be yellow. In that case, cues may be required to achieve acceptable scene-to-scene color balance.

In our tests, using the answer print timing tape for 5384, without making corrections, release prints from intermediates were well-matched for color balance compared to the answer print. Without a need for correction factors in making duped negatives, Eastman color print film 5384 will provide improved intercut timing response for all laboratories, particularly those which may make no corrections at present.

Spark Protection

The blue spectral sensitivity shift in 5384 gives improved protection against the effect of static discharges. Figure 13 shows the relative energy of a spark discharge. As indicated, much of this energy is in the ultraviolet portion of the spectrum between 350 and 400 nm in wavelength and, therefore, in an area where print film traditionally has substantial rawstock sensitivity (Fig. 9). The 5384 has less sensitivity in this area and, therefore, shows extra protection from the results of a spark discharge. Figure 14 shows the response of both 5384 and 5383 to a spark discharge.

Printing

Printing Filters

Printing recommendations are unchanged for 5384; the Kodak Wratten filter No. 2B is the recommended printing filter. However, because of the shifted blue spectral sensitivity of 5384, there is very little speed or contrast difference if a Kodak Wratten filter No. 2E is used in place of a 2B. Table 3 illustrates the printing differences that can be expected between 5383 and 5384 with 2B and 2E filters.

Safelights

Kodak safelight filter No. 8 (dark yellow) is the recommended safelight filter for 5384. Filter No. 8 is also recommended for 5383. In addition, a sodium vapor lamp with Kodak Wratten gelatin filters Nos. 23A and 53 plus neutral density filters can also be used. As shown in Fig. 15, the same orange safelight "notch" exists between the red and green sensitivities of 5384 and 5383.

Because oversized bulbs are sometimes used in safelights, filters should be checked periodically for fading or damage. We suggest normal filter replacement on an annual basis.

Sound Track Exposure/Print Densities

Sound-printing requirements and practical sound performance of Eastman color print film 5384 are similar to those for Eastman color SP print film 5383. Figure 16 shows curves of optimum print density versus sound negative density for a prototype coating of 5384 compared to 5383 film. A negative density of 2.45 gave cancellation at print densities of 1.5 on both print films. Lower negative densities would require slightly lower densities for 5384 film than for 5383 film. Within the normal operating range of print densities, there were no significant differences in sound reproduction quality. Cross-modulation tests should be performed to determine the optimum conditions for each laboratory's specific equipment, however.

LAD (Laboratory Aim Densities)

The Laboratory Aim Densities (that is, the status A densities) for 5384 film are similar to 5383. The aim densities are: red 1.08, green 1.04, and blue 1.03. This yields a gray having 1.0 visual density (1.0 END) for a xenon-arc projection light source.

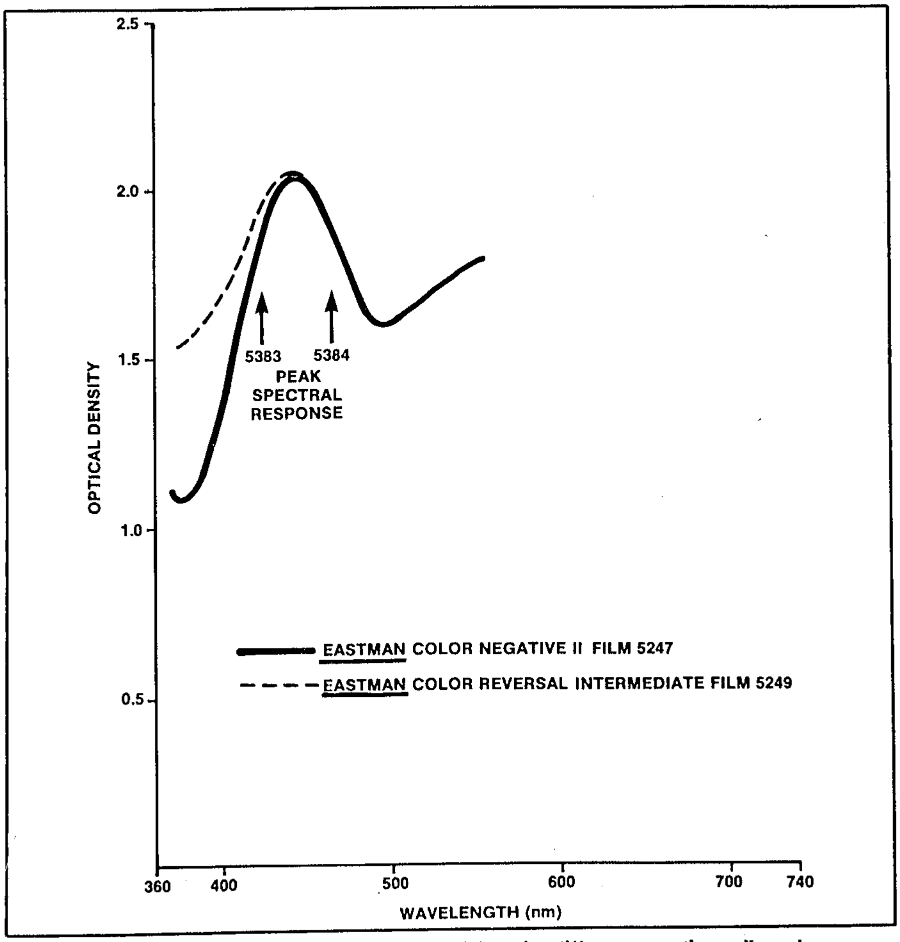

Figure 12. Comparison of print film spectral sensitivity with different negative yellow dyes.

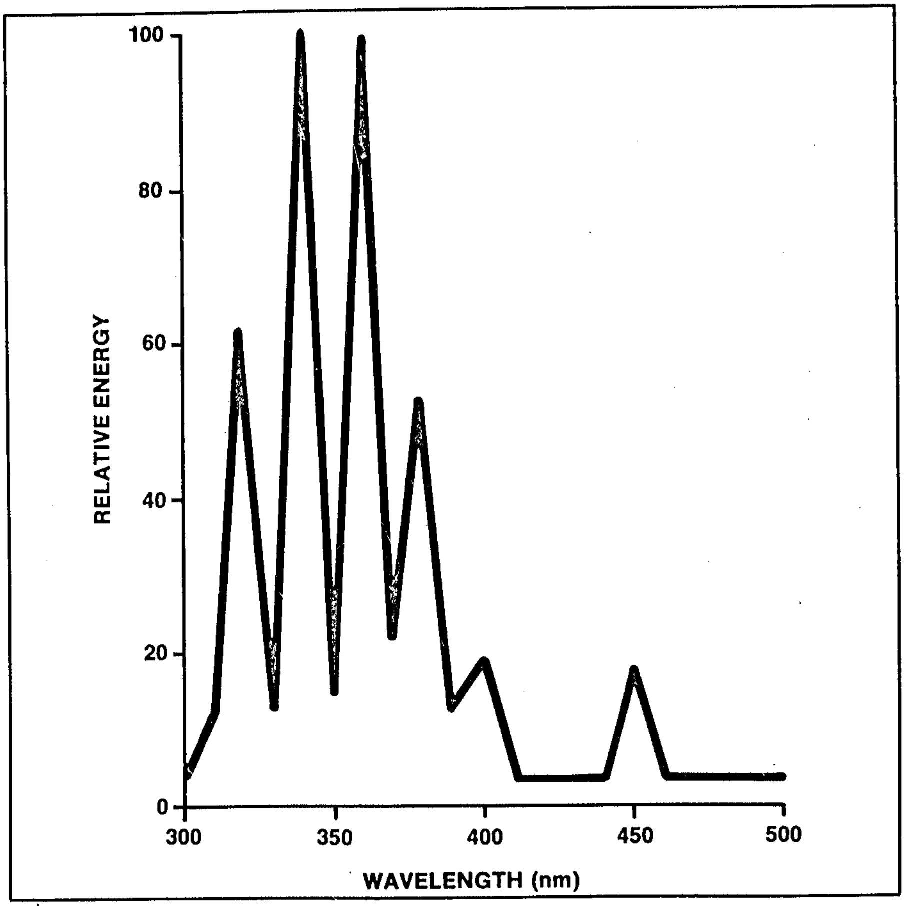

Figure 13. Relative energy of a spark discharge.

Processing

Accompanying the introduction of Eastman color print film 5384/7384 are slight modifications to process ECP-2. This modified process is designated process ECP-2A. Some changes are necessitated by the processing characteristics of the new print film, while others are the result of an effort to improve process ECP-2. Process ECP-2A differs from process ECP-2 primarily in two respects:

1. Persulfate bleach is the recommended bleach for process ECP-2A, whereas it is the alternative choice for process ECP-2. The persulfate bleach is recommended because it appears to be the best choice in the future for all motion picture products for environmental reasons. Many laboratories are already using persulfate bleach in their process ECP-2. Ferricyanide bleach is an acceptable alternative choice for process ECP-2A.
2. Process ECP-2A specifies a slightly higher level of bromide in the color developer replenisher. This increase in bromide is required when processing 5384 in order to maintain the present recommended level of 1.72 g/L in the color developer tank.

Other modifications have been made to the first fixer. A summary of these changes is found in Table 4. In the following paragraphs, each of the modifications will be discussed individually.

Color Developer

In process ECP-2A, the bromide concentration in the developer replenisher is increased from 1.20 to 1.60 g/L sodium bromide. Eastman color print film 5384 releases less bromide to the developer than does 5383 film. Consequently, to maintain the present tank concentration at 1.72 g/L, the replenisher bromide concentration must be increased. Sensitometric variations due to bromide concentration are shown in Fig. 17.

If only 5384 were being processed, maintaining the desired 1.72 g/L bromide level in the tank would not be a problem. However, during the crossover to 5384, most laboratories will be processing both 5383 and 5384 films. In order to maintain chemical and photographic control of the print process, the laboratory must devise a method of adjusting the bromide concentration of the developer based on the product mix. There are several methods by which this may be ac-

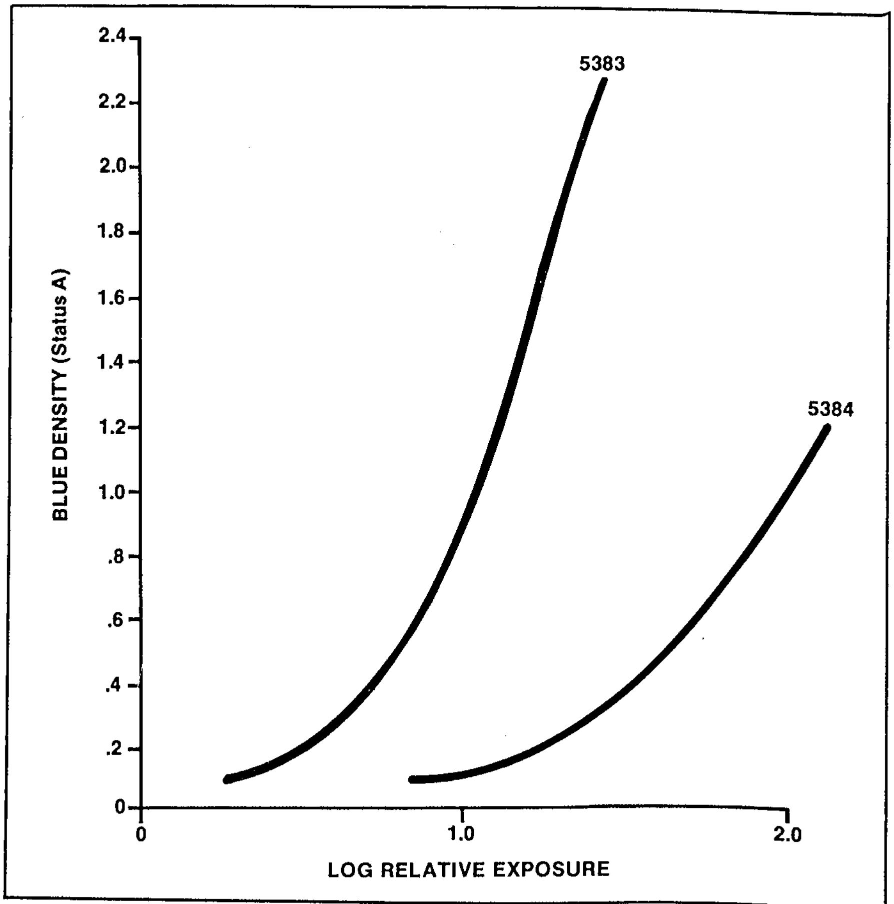

Figure 14. Effect of a spark discharge on Eastman color print films.

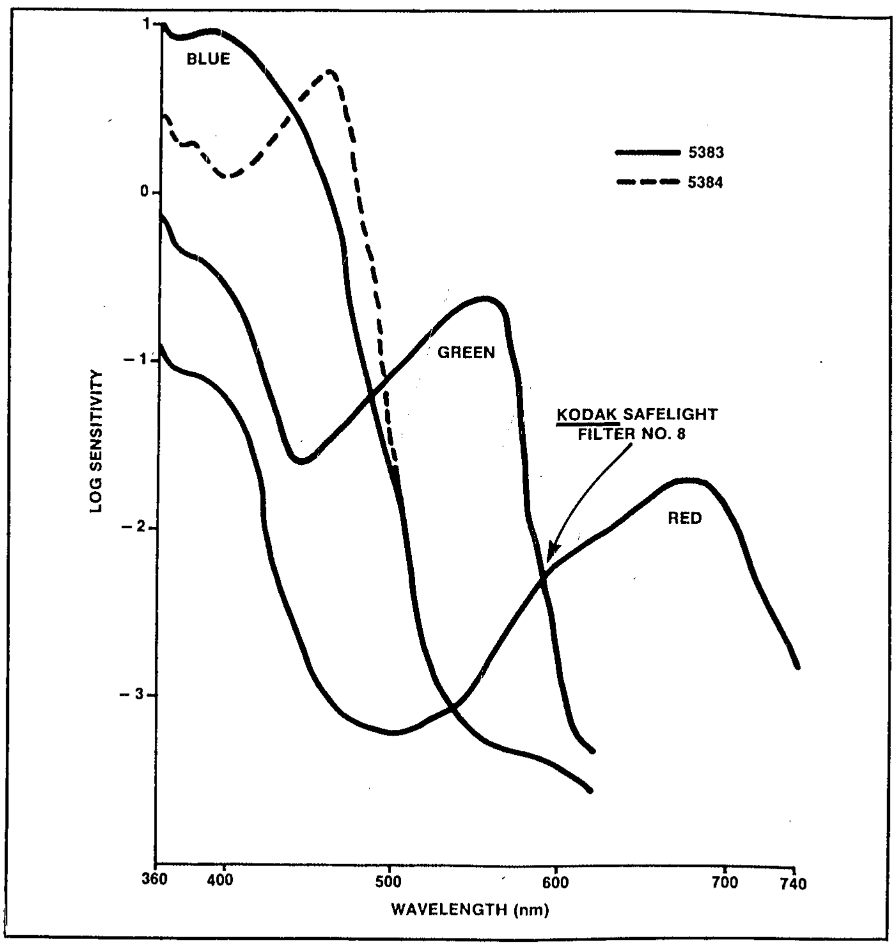

Figure 15. Use of safelight filters with Eastman color print films.

Table 3 — Effect of Printing Filter Change (2B → 2E)

Speed Loss (Blue)		Contrast Effect (Blue)	
5384	5383	6384	5383
~2–3 lights	~11–12 lights (1 stop)	No Change	~+5%

Table 4 — Summary of Changes for Process ECP-2A

Solution	Change (from Process ECP-2)
Developer	— Replenisher: 1.60 g/L NaBr
First Fixer	— Persulfate bleach sequence (recommended) Tank: 0.50 g/L KI Replenisher: 0.70 g/L KI — Ferricyanide bleach sequence (alternative) Tank: pH 5.0 CD-2 contamination less than 0.05 g/L
Bleach	— Persulfate bleach recommended — Ferricyanide bleach alternative choice

complished. The most straightforward is to monitor periodically the bromide concentration in the developer tank and adjust as needed. Alternatively, a separate bromide replenishment system may be installed that would be used only when 5384 film is processed. Finally, the developer tank concentration may be adjusted daily based on the footage of 5384 film processed or the fraction of 5384 film in the product mix.

First Fixer

When using persulfate bleach, the potassium iodide concentration in the first fixer should be increased to 0.50 g/L in the tank and 0.70 g/L in the replenisher. Iodide acts as a "grain scrubber" to prepare the silver surface for the adsorption of the accelerator compound. Incomplete bleaching will occur if sufficient iodide is not present in the first fixer. The increased iodide is not required when using the alternative choice, ferricyanide bleach.

If the alternative ferricyanide bleach is used, process ECP-2A specifies a lower level of CD-2 contamination in the first fixer and a lower fixer pH. CD-2 contamination level is reduced from 0.20 g/L (process ECP-2) to 0.05 g/L (process ECP-2A), while the fixer pH is reduced from 5.8 to 5.0. These changes help avoid magenta stain in processes using ferricyanide bleach, particularly under some marginal processing conditions.

Bleach

The recommended bleach for process ECP-2A is persulfate bleach; ferricyanide bleach is an alternative choice. As discussed previously, persulfate bleach is recommended because it appears to be the most environmentally acceptable bleach for motion picture processes. There are no formulation changes for either persulfate or ferricyanide bleach in process ECP-2A.

Drying

As the result of its thinner blue layer, Eastman color print film 5384 has approximately 10% less wet load than does Eastman color SP print film 5383. This is illustrated in a comparison of the emulsion swell profiles comparing 5383 and 5384 films in process ECP-2A (Fig. 18). If drying conditions for 5383 are acceptable, they will also be acceptable for 5384. If 5383 is currently being overdried, conditions may need to be reduced for 5384.

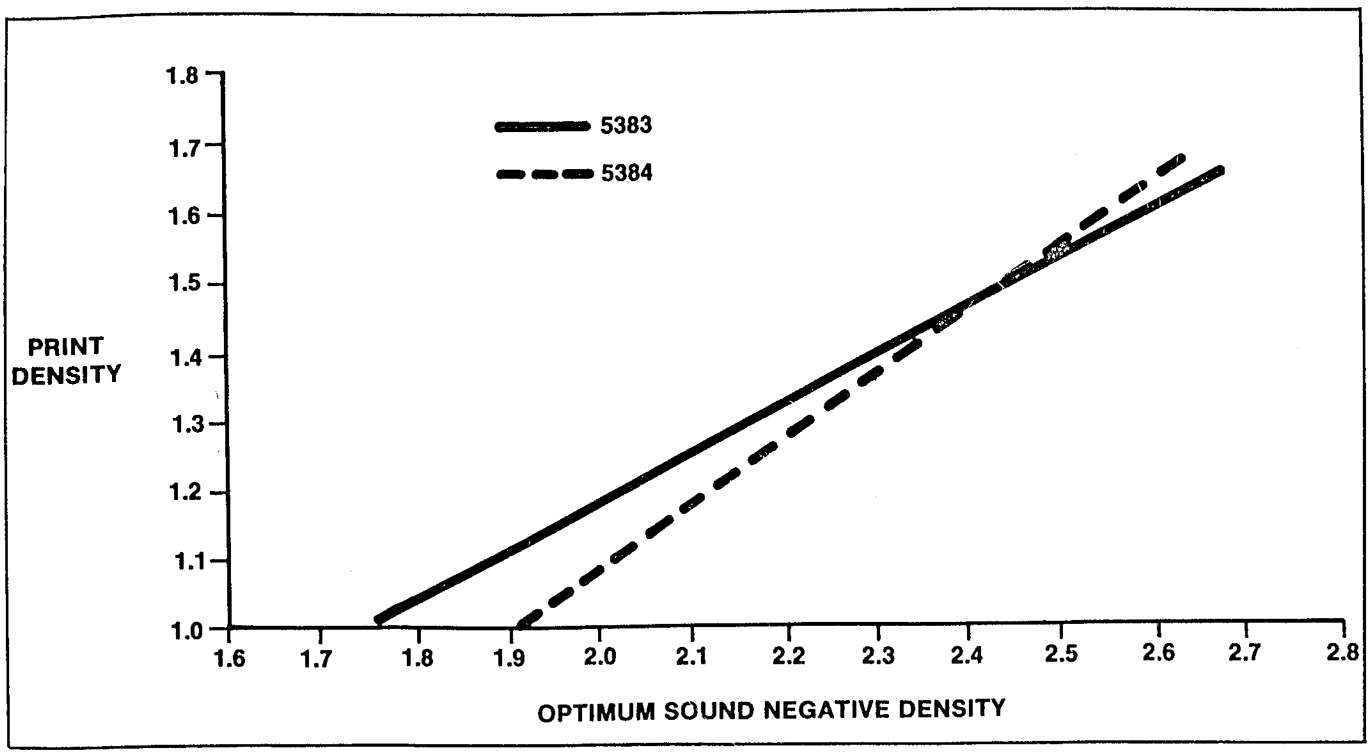

Figure 16. Sound cross-modulation distortion data.

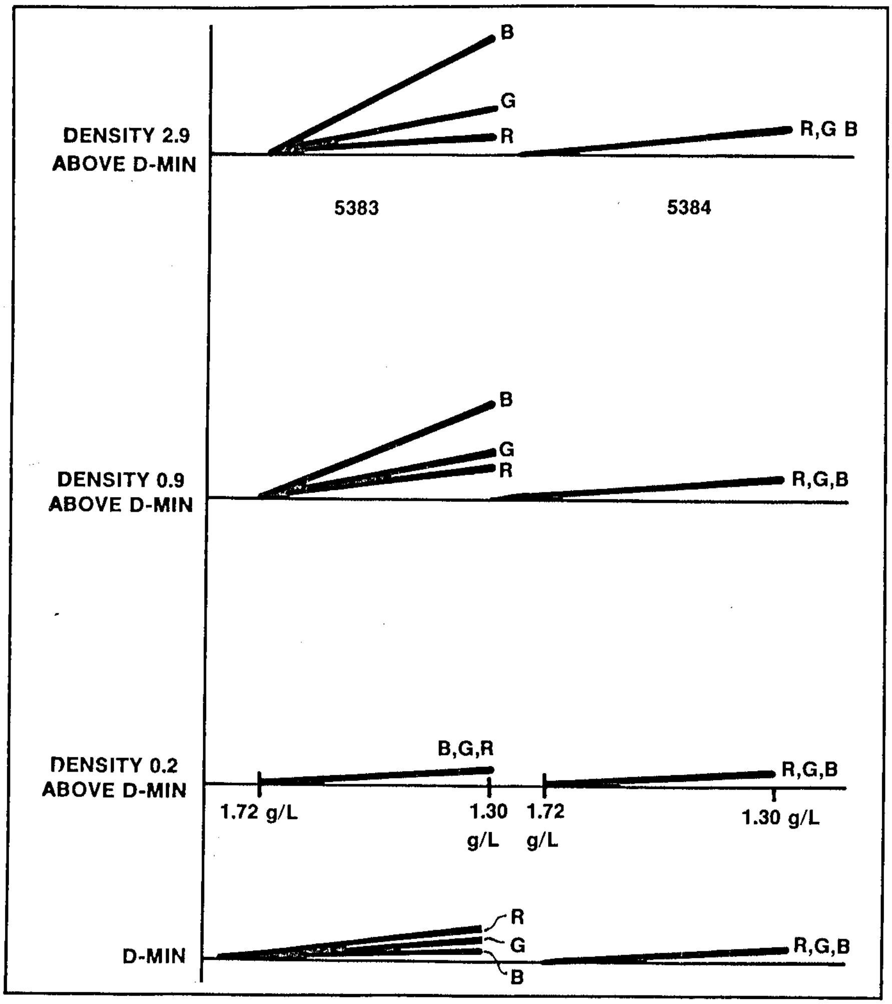

Figure 17. Effect of developer sodium bromide variations on Eastman color print films.

Conclusion

Eastman color print film 5384/7384 is a new print film that we believe is an excellent answer to customers' expressed needs. Combining the benefits of process ECP-2 (with shortened wet processing time), improved dark-keeping dye stability, and reduced sensitivity to process variations, the new film joins previous print films in the same tradition established since the introduction of Eastman color print films in the early 1950's.

Acknowledgments

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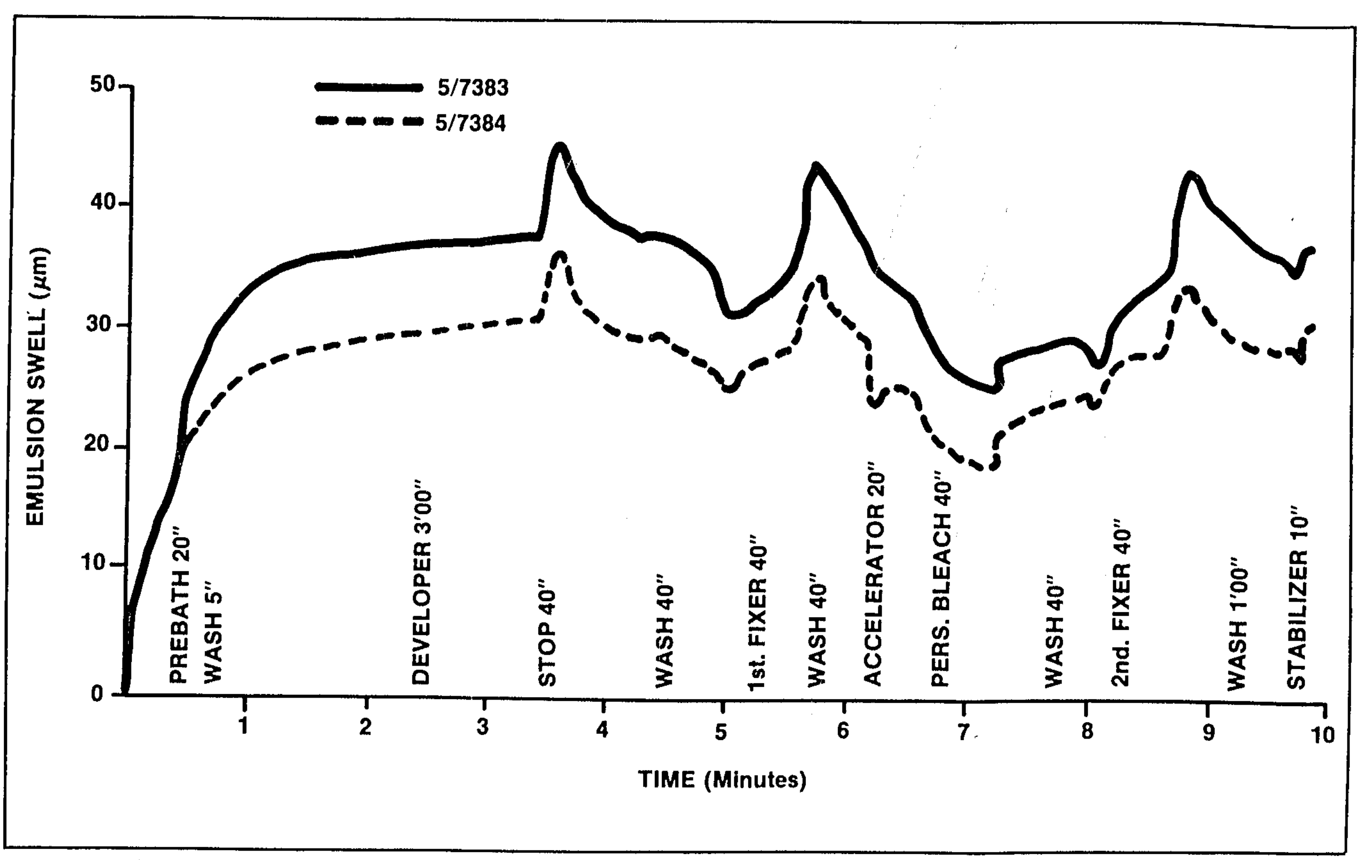

Figure 18. Typical emulsion swell profiles of Eastman color print films in process ECP-2A.