New Fujicolor High-Speed Negative Film and Fujicolor Positive Film

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This article describes two new motion-picture films recently introduced by Fuji Photo Film Co., Ltd.: the ultra-high-speed Fujicolor High-Speed Negative Film AX 8514/8524, with an exposure index of 500; and Fujicolor Positive Film LP 8816/8826. The key features of each of the new films are discussed, together with the techniques used to obtain higher speed and improved picture quality. The new films are compared with earlier versions, and the advantages explained.

The first color negative film developed by Fuji Photo Film Co., Ltd. was slow, with an exposure index of 25. That was in 1955. Since then, the company has worked hard to develop the technology required to improve picture quality and film speed. In 1969, it succeeded in reaching a film-speed level of 100. For the next ten years or more, however, its film speed remained at that level.

New Color Negative Films

In 1980, Fujicolor High-Speed Negative Film A250 was launched, with an exposure index of 250. It was then the world's fastest color negative motion-picture film. The film won the Academy Award of Merit for technical achievement and other prizes, and ushered in the age of high-speed motion picture films. In 1983, Fujicolor High-Speed Negative Film AX 8512/8522 was introduced, with an exposure index of 320, and it is currently in wide use. The latest to be introduced, an ultra-high-speed film with an exposure index of 500, is Fujicolor High-Speed Negative Film AX 8514 (35mm)/8524 (16mm). (Fig. 1).

Incorporating newly devised, sophisticated emulsion techniques, the 8514 film offers both greater film speed and better picture quality than the 8512. Its features and the technology used to attain higher speed and improved picture quality are explained in the following sections.

Key Features

Film Speed

Exposure index: 500 for tungsten light (3200K); 320 for daylight (with daylight filter).

Like the 8512 film, the 8514 is balanced for 3200K tungsten light. It is exposed in daylight through a daylight filter, such as the Fuji LBA-12 or Wratten 85. For shooting subjects illuminated by fluorescent light, the filters and exposure indexes in Table 1 will serve as reference. The film's exposure index of 500 is equivalent to ⅔-stop faster than the speed of the 8512 film. Lens aperture and illumination level relationships are shown in Table 2. Figure 2 shows a comparison of the characteristic curves of the 8514 and the 8512 films. The blue, green, and red sensitive layers of the 8514 film are respectively 0.2 log E (⅔-stop) faster than the 8512's.

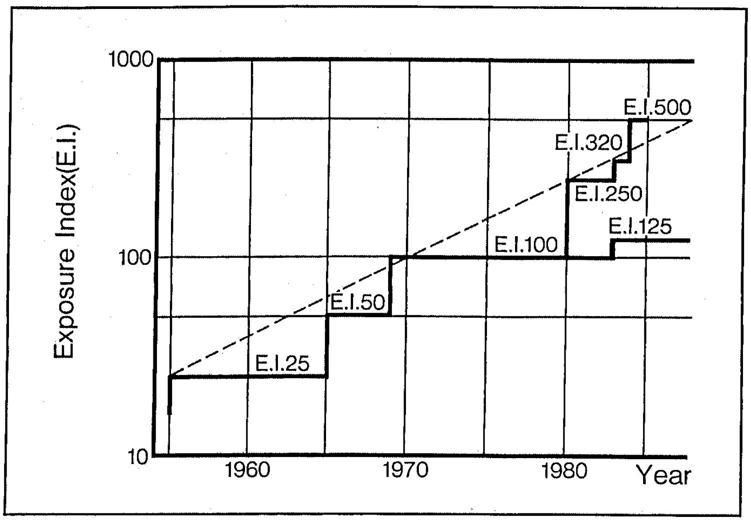

Figure 1. Speed transition of Fujicolor negative films for motion-picture use.

Table 1 — Filters and Exposure Indexes Under Fluorescent Lighting

Lamp Types	Filters	Exposure Indexes
White light fluorescent lamp of good color rendition (W-SDL)	Fuji LBA-8 or Kodak Daylight Filter No. 85C	400
White light fluorescent lamp of ordinary color rendition (W)	CC-20R	400
Daylight type fluorescent lamp (D)	Fuji LBA-12 or Kodak Daylight Filter No. 85	320

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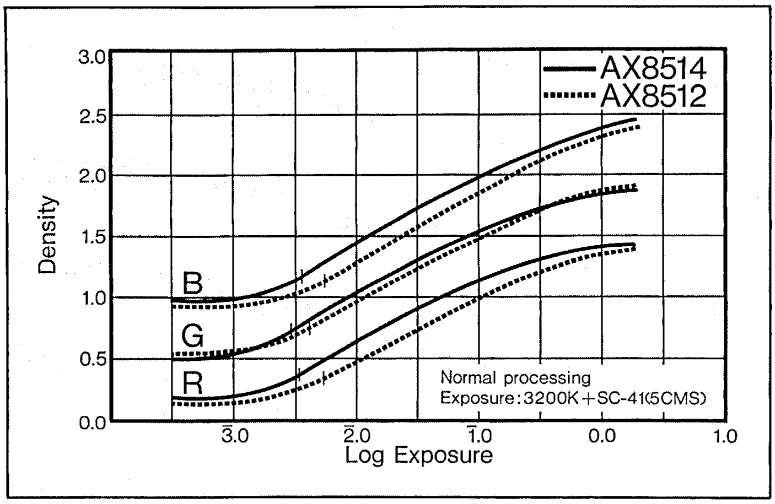

Figure 2. Characteristic curves of AX 8514 and AX 8512.

Tone Reproduction

As shown in Fig. 2, the tone reproduction of the 8514 is almost the same as the 8512 film, except that the straight-line portion of the characteristic curve of the blue-sensitive layer has been improved by using three strata instead of the two used in the 8512 (Fig. 3). This improvement insures less tonal deviation between different density areas, better gray balance from highlight to shadow, and more natural tone reproduction. The 8514 will intercut very well when used together with the normal-speed Fujicolor Negative Film 8511.

Graininess

The most difficult part of designing a high-speed film is avoiding high granularity while increasing the film speed. In the new film, this has been done with the aid of newly developed ultra-high-speed emulsion and high picture-quality techniques. (These techniques will be explained later in this article.)

Features of the 8514 film include improved graininess in the shadow areas (low-density areas of the negative), an important factor in high-speed films. The graininess of the high-density or shadow areas of the print does not, as a rule, become easily apparent, but inadequate printing density of the shadow areas can cause the grains to appear coarse. This is especially true when the film has been underexposed and cannot be printed to

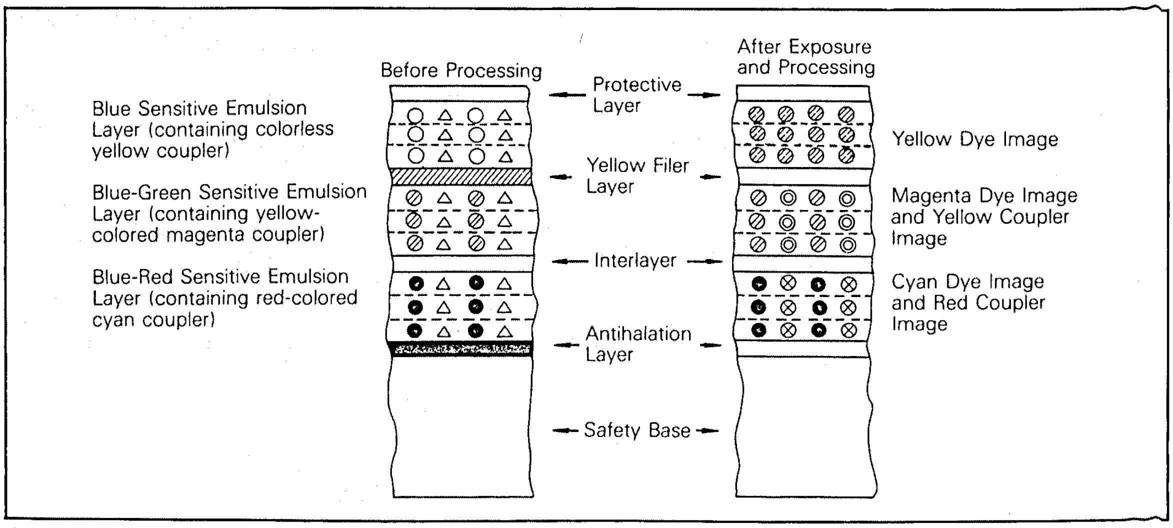

Figure 3. Film structure.

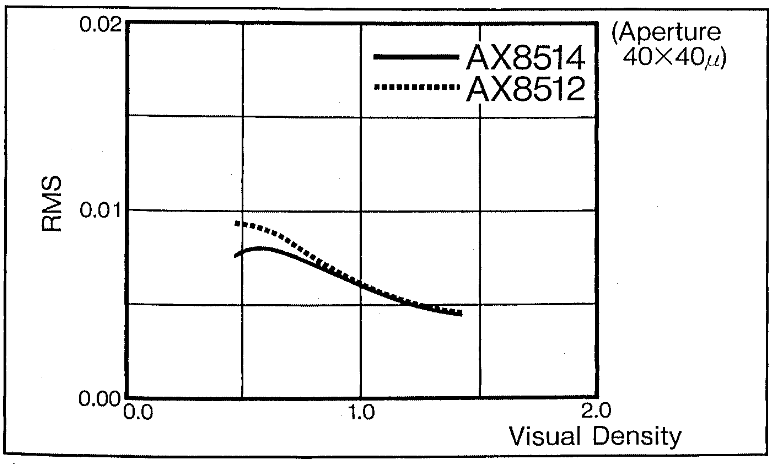

Figure 4. RMS granularities of AX 8514 and AX 8512.

sufficient density. The advantage of the 8514 film is that its grains do not stand out too conspicuously in such cases.

Fig. 4 shows the root mean square (RMS) granularity of 8514 film. This is a mathematical quantity obtained from actual measurement of the grains. It shows that the granularity of the low-density areas of the new 8514 film (the high-density areas of the print) is lower than that of the 8512, indicating that the grains are finer.

Sharpness

The emulsion of the 8514 film has been made 7% thinner than that of the 8512, with the aid of the high picture-quality techniques which will be mentioned later. Besides finer grain, the super DIR coupler used in this emulsion also insures improved picture sharpness. Figure 5 shows the contrast transfer function (CTF) of the two films. This is a physical attribute which serves as a measure of film sharpness. It shows that the new 8514 film's response in the high-frequency range has been improved to permit more efficient reproduction of fine detail.

Since dark subjects are taken mostly with high-speed films, the 8514 film will permit the use of a smaller aperture within the superior range of the lens, and also with greater depth of field, so that the pictures will appear sharper.

Push-Processing

The effective speed of a film can be made faster by using a longer development time or by raising the development temperature. This is called push-processing. Compared to the 8512 film, the 8514 film promises less fogging, faster effective speed, less contrast deviation and grain coarsening, and better color reproduction. But since push-processing can conceivably degrade the image, it is recommended that it not be push-processed more than 1 stop if picture quality is of primary importance, and not more than 1½ stops if film speed takes precedence. If push-processing is employed, the processing lab should be consulted.

Other Features

Color Reproduction

Like the 8512 film, the 8514 film promises rich, natural colors, but its reproduction of the grays from highlight to shadow has been improved and stabilized by adjusting the straight-line

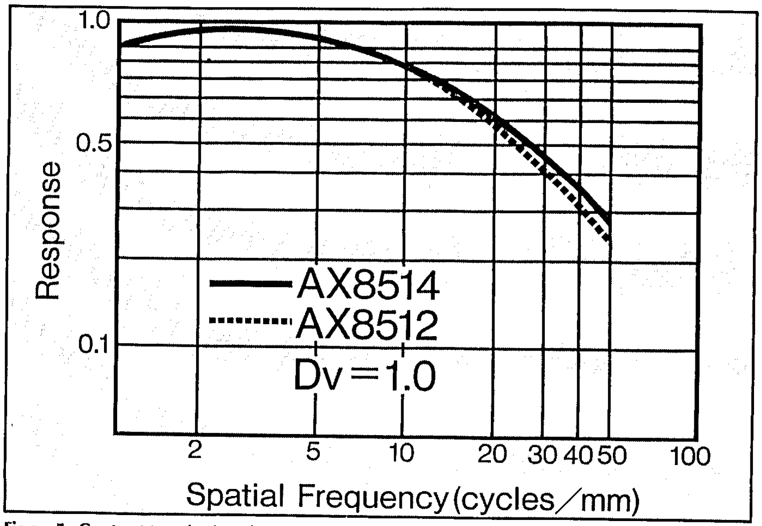

Figure 5. Contrast transfer function curves of AX 8514 and AX 8512 (visual density: 1.0).

Table 2 — Tungsten Light, 24 Frames/sec, Lens Aperture/Illumination Level for 1/50-sec Exposure

Lens aperture (f)	1.4	2	2.8	4	5.6	8	11
Foot-candles	5	10	20	40	80	160	320

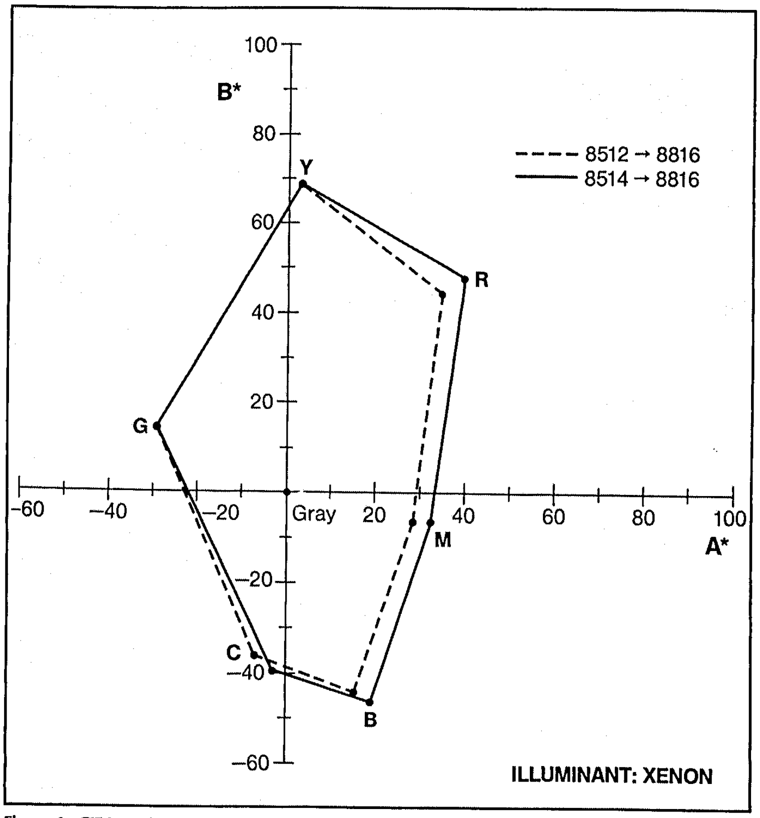

Figure 6. CIE Lab diagrams of AX 8514 and AX 8512.

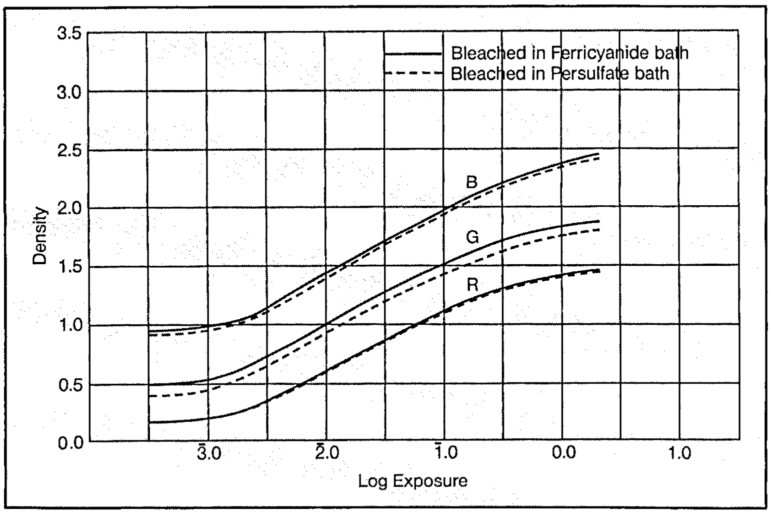

Figure 7. Processing with ferricyanide bleach and persulfate bleach.

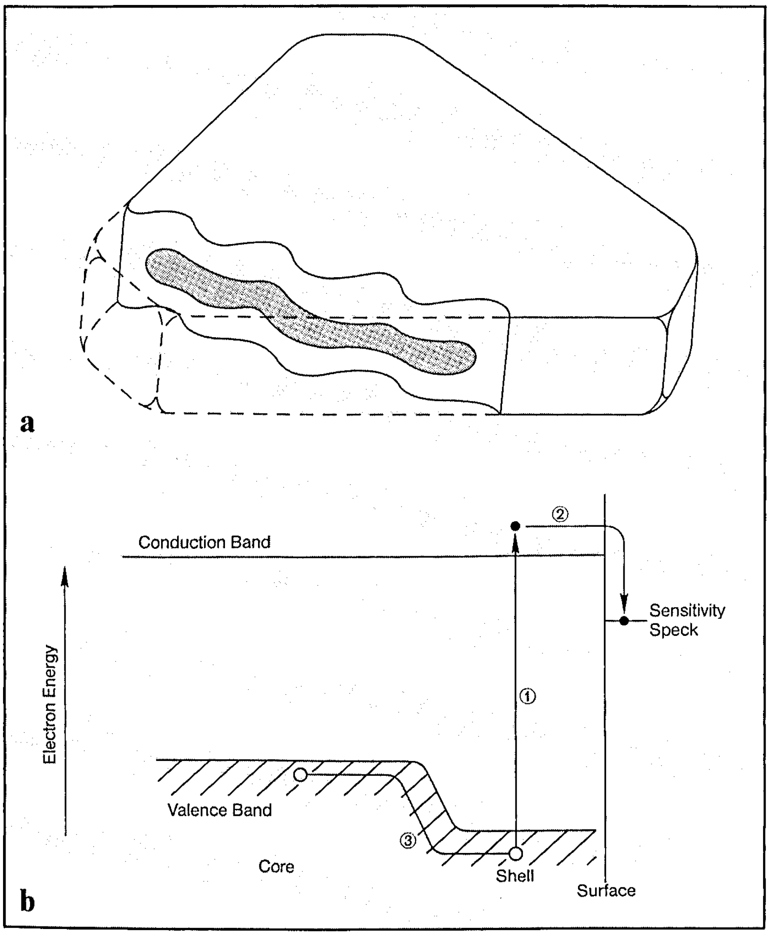

Figure 8. Double structure grain and division of functions. (a) Double structure gain. Shell gathers photoelectrons and forms latent image (silver specks with high efficiency). Core captures positive holes and prevents them from recombining with the photoelectrons; prevents the grain from coarsening by development-inhibiting action. (b) Illustration of the separation of photoelectrons and positive holes. (1) Creation of photoelectrons (●) and positive holes (○) by light absorption. (2) Trapping photoelectrons to the sensitivity speck. (3) Movement of the positive holes into the grain's core.

portion of its characteristic curve. Figure 6 shows the color reproduction of both films as measured with a colorimeter. There is a very slight difference in the color reproduction of the two films. Like the 8512 film, the 8514 also exhibits excellent color reproduction when exposed in mixed lights such as fluorescent, daylight, and tungsten light.

Color-Image Stability

Incorporating color-dye stabilizing techniques (called low fading [LF] techniques), the 8514, like the 8512, exhibits low color-image discoloration and fading. Stored at 22° C, at 40% relative humidity (RH), its contrast decreases less than 10% in 100 years, as estimated by the accelerated tests.

Processing

The new 8514 film is processed in the same formula and under the same conditions as the 8512 film. It can, of course, be bleached in either a ferricyanide or a persulfate bath (Fig. 7). Its processing consistency is the same as that of the 8512. It therefore yields consistently excellent processing results, as confirmed by survey results from the major processing labs throughout the world.

Film Identification

The 8514 film is identified by the latent-image code "N4" photo-printed in the film edge. The 8512 film is coded "N2."

Techniques Used for Achieving Ultra-High Speed

Double-Structure Grain

The silver halide grain is double-structured; i.e., it has a high-iodide-content core and a low-iodide shell. The core is designed to absorb a large quantity of light so that it releases photoelectrons to be trapped in the shell. The shell uses these photoelectrons and those generated in the shell to form silver specks which constitute the latent image. On the other hand, the positive holes* created by light absorption are held captive in the core to deprive them of the chance to cause oxidation. The photoelectrons and positive holes are thus kept apart to lessen their possibility of recombination. During the advanced stage of

* When light strikes the silver halide grain, electrons will move out of it and leave a positive electric charge in their places, and this positive charge is called a "positive hole."

development, the core's iodide ions produce a development-inhibiting effect which prevents the dye clouds from becoming too large, and thus the picture grains from turning coarse (Figs. 8 and 9).

A-Coupler

When an exposed silver halide grain in the emulsion starts development, the A-coupler in the emulsion releases an amplifier which protects the silver specks in the other exposed silver halide grains around it from destruction by oxidized products. The amplifier is designed so that it will act only on its neighboring grains. It thus insures the utilization of practically all of the silver specks available to permit the forming of an image on the high-speed film without coarsening the picture grains (Fig. 10).

Techniques Used for Achieving High Picture Quality

L-Coupler

This coupler is composed of latex-like particles of polymer chains linked with color-forming groups. This makeup has permitted reducing the volume per color-forming group to one-half of that used in conventional couplers. Although color-forming groups exhibit diminished response when linked to high-molecular chains, this advantage has been overcome by meticulous molecular designing. Such technical breakthrough has not only permitted reducing the volume per color-forming group to less than one-half that of the conventional coupler, but has also resulted in reduced light scatter in the emulsion and, consequently, a high level of resolution (Fig. 11).

Super Development-Inhibitor Releasing (DIR) Coupler

The molecular structure of this coupler is designed to release the development-inhibitor, which has the following features: it produces the desired development-inhibiting effects; it exhibits powerful diffusibility; and it will decompose quickly in the developing solution and lose its inhibiting ability. This technical innovation has made it possible for the development-inhibitor to reach much farther out than the conventional DIR coupler. This results in much stronger development-inhibiting action in remote layers and along image borders, and consequently, improved picture

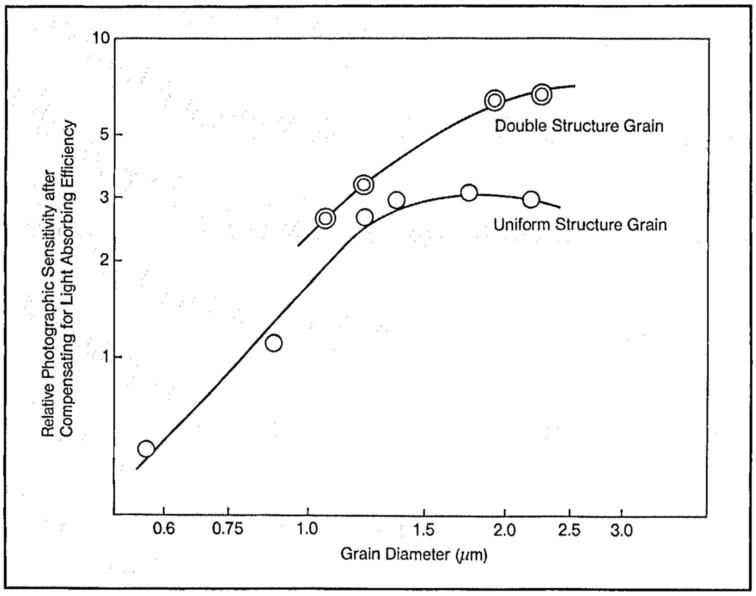

Figure 9. Grain size vs. sensitivity of the double structure grain and uniform structure grain (conventional grain).

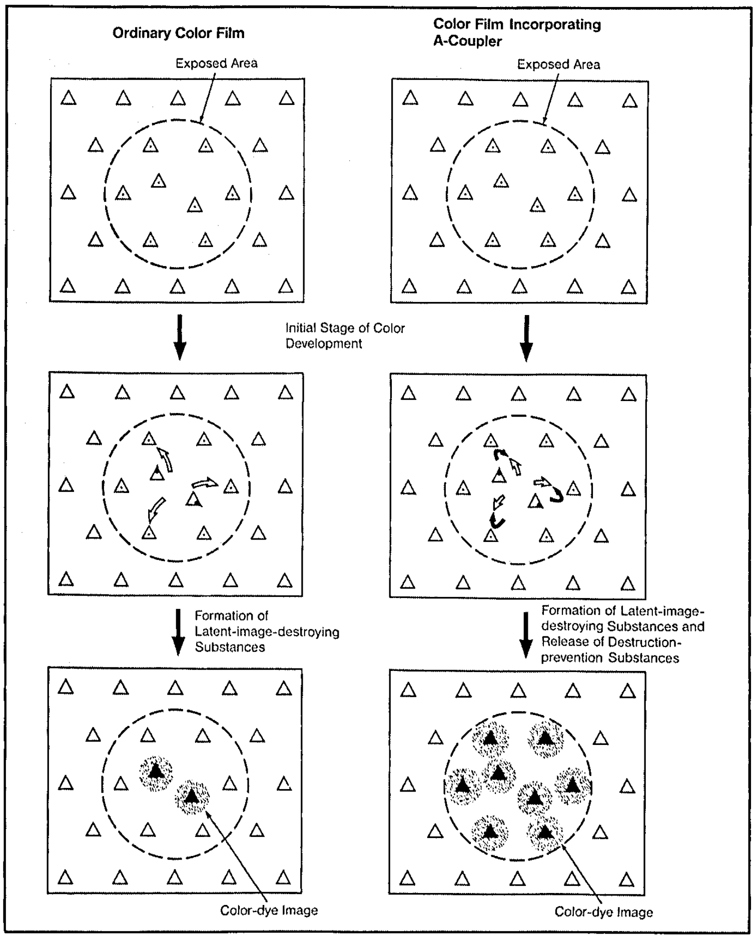

Figure 10. Function of the A-coupler.

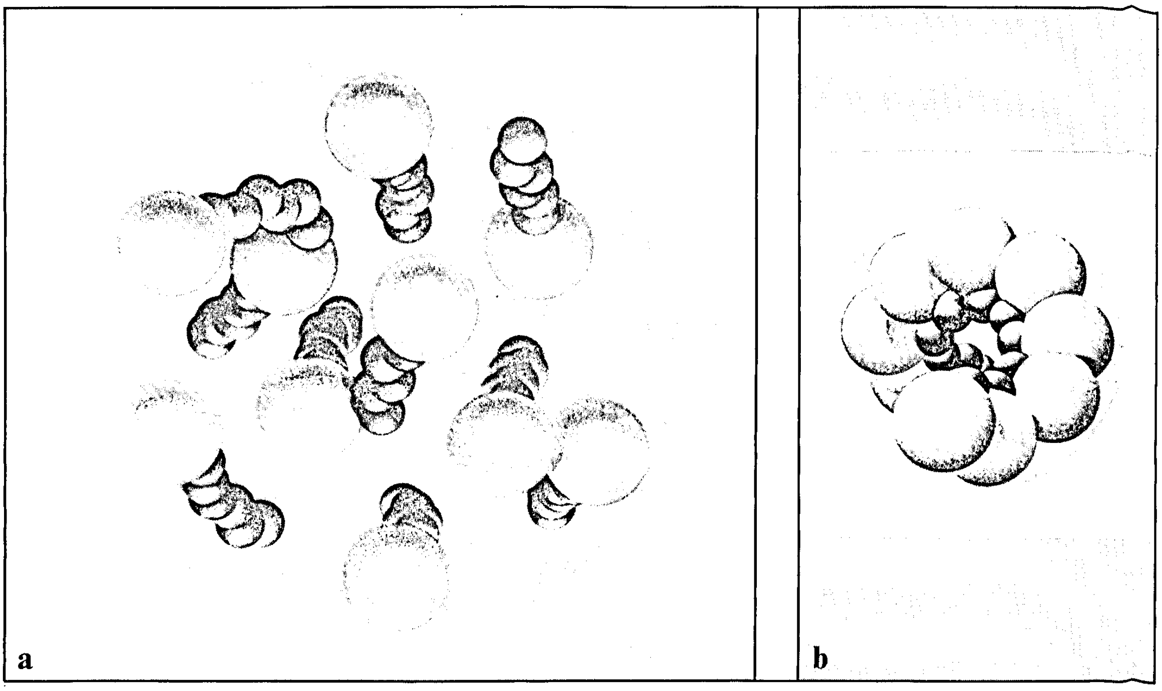

Figure 11. Typical construction of the L-coupler: (a) conventional coupler; (b) L-coupler.

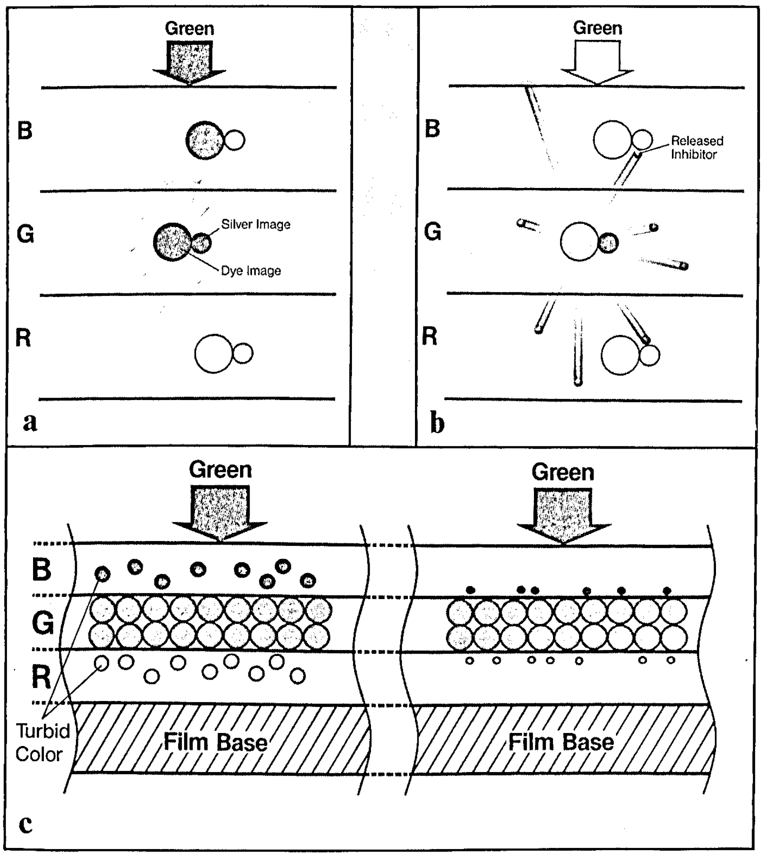

Figure 12. Function of the super DIR coupler: (a) conventional DIR coupler; (b) super DIR coupler; (c) conventional DIR coupler and super DIR coupler.

sharpness and reduced color desaturation (Fig. 12).

New Color Positive Film

Preserving precious films of artistic, cultural, and other worth for posterity in the best condition possible has always been a concern of those taking part in motion pictures, and it is one of the subjects of research at Fuji. The new Fujicolor Positive Film LP 8816 (35mm)/8826 (16mm) will serve that interest well, with its extended print life achieved through substantial improvement of the dark-fading property of its cyan dye. This new film also features improved color reproduction, softer highlight contrast, and many other improvements.

Color-Image Storage Life

The new LP 8816 film has been made far more resistant to dark-fading than the HP 8814 which it replaces by incorporating a newly developed cyan coupler which prolongs, by a wide margin, the life span of the cyan dye formed during development. Compared to the HP 8814, which shows appreciable cyan-dye fading when stored for about 7 years at room temperature, the life of the new LP film's cyan dye is about 70 years under identical conditions. This is a remarkable ten-fold increase in the life span of the cyan dye. However, since the yellow and magenta dyes in the print will also fade in time, and since the life of the cyan dye has been prolonged to outlast that of the yellow dye in the new LP 8816 film, it is the yellow dye that now determines the life of the print.

Figure 13 illustrates color-image storage life derived from accelerated test data using the Arrhenius equation to predict dye stability. The solid lines show the density changes of the LP 8816's yellow dye with 60% RH at 17, 22, and 30° C. The dashed lines show the density changes of the HP's cyan dye under identical conditions. Note that the dark-storage life of the LP 8816's dye image has been dramatically prolonged and that when 10% fading is taken as the limit of print life, it will last about 50 years at 22° C, and 100 years at the lower temperature of 17° C.

Color Reproduction

In the reproduction of skin tones and grays, the HP's skin tones have a tendency to become reddish when the grays are well color-balanced, and the grays become cyan tints when the skin tones are well color-balanced. But, by shifting the peak wavelength of spectral sensitivity in the LP's green-sensitive layer about 14 nm toward the longer wavelength side, the reproduction of skin tones and grays has been greatly improved (Fig. 14). This improvement also lends itself to the reproduction of more pleasing colors generally.

A comparison of the color reproduction of the LP 8816 and HP 8814 is shown in the chromaticity diagram in Fig. 15. As shown in the diagram, the LP's yellow leans toward lemon yellow, and its sky blue, where the cyan tint has been eliminated, now looks more natural.

Tone Reproduction

The tone reproduction of the new LP 8816 has also been appreciably improved. Figure 16 shows a comparison of the characteristic curves of the LP 8816 and the HP 8814. The tone reproduction of the red-and-green sensitive layers of the two films is very similar, but the blue-sensitive layer of the LP 8816 exhibits a slightly softer highlight and higher shadow contrast, as shown. This is designed to provide deeper shadows and permit subtle tone reproduction in the highlights at the same time. The effect is a noteworthy smoothness of the tonal continuity

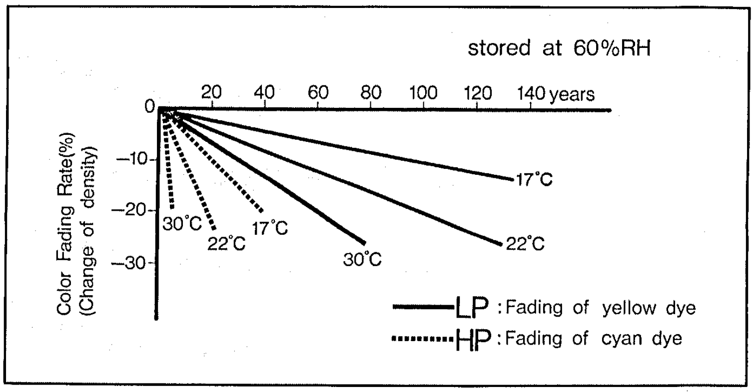

Figure 13. Dark-keeping stability test results of the Fujicolor positive films LP 8816 and HP 8814.

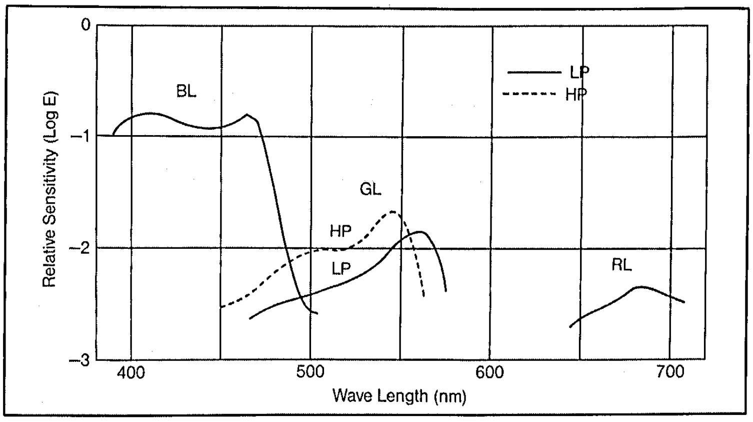

Figure 14. Special sensitivities of the Fujicolor positive films LP 8816 and HP 8814.

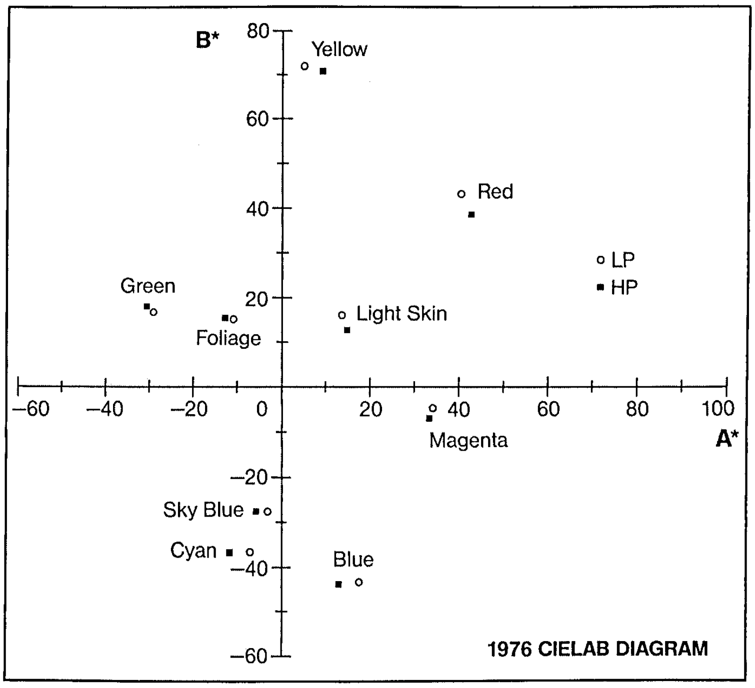

Figure 15. Comparison of color reproduction between the Fujicolor positive films LP 8816 and HP 8814.

from highlights to shadows. On the other hand, the higher shadow contrast of the blue-sensitive layer and the improved shadow balance achieved by a slight change made in the spectral density distribution of the cyan dye combine to provide considerably improved shadow balance.

Processing

The conditions for processing the LP 8816 are the same as those for the HP 8814 film, and it can be bleached in either the ferricyanide or persulfate bath. Like the HP 8814, its photographic properties are little influenced by changes in processing chemicals, time, and temperatures. The conditions for drying and drying speed are also the same as those for the HP 8814 film.

Sound Characteristics

The sound characteristics of the new LP 8816 are practically the same as that of the HP 8814. Figure 17 shows the optimum print density areas of both films relative to sound negative density. It shows that compared to the HP 8814, the optimum printing density of the new LP 8816 becomes somewhat lower as the negative density increases. However the resulting density differences do not show up as differences in the actual output level of sound.

Other Characteristics

Compared to the HP 8814, both the raw and processed LP 8816 films feature greater emulsion-surface slidability and strength and improved printer and projector behaviors. The other physical properties of the LP 8816 are the same as that of the HP 8814.

The processed LP 8816 film is distinguished from the HP 8814 by the code "LP" printed on the film edge.

Conclusion

As we have seen, the 8514 film is faster than the 8512 and yields better quality image at the same time. It is designed to allow the user to step daringly into the frontiers of motion-picture imaging. The LP 8816 provides longer color-image life, better color reproduction, softer highlight contrast, and many other improvements. It is hoped that these films will be of service for many years in the motion-picture and TV industries, and in various other fields.

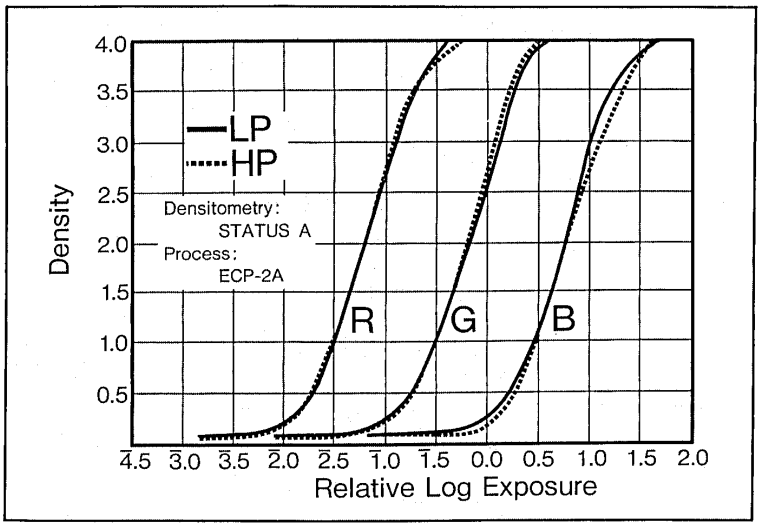

Figure 16. Comparison of characteristic curves between the Fujicolor positive films LP 8816 and HP 8814 (the *R*, *G*, and *B* curves are separated from each other to avoid overlapping).

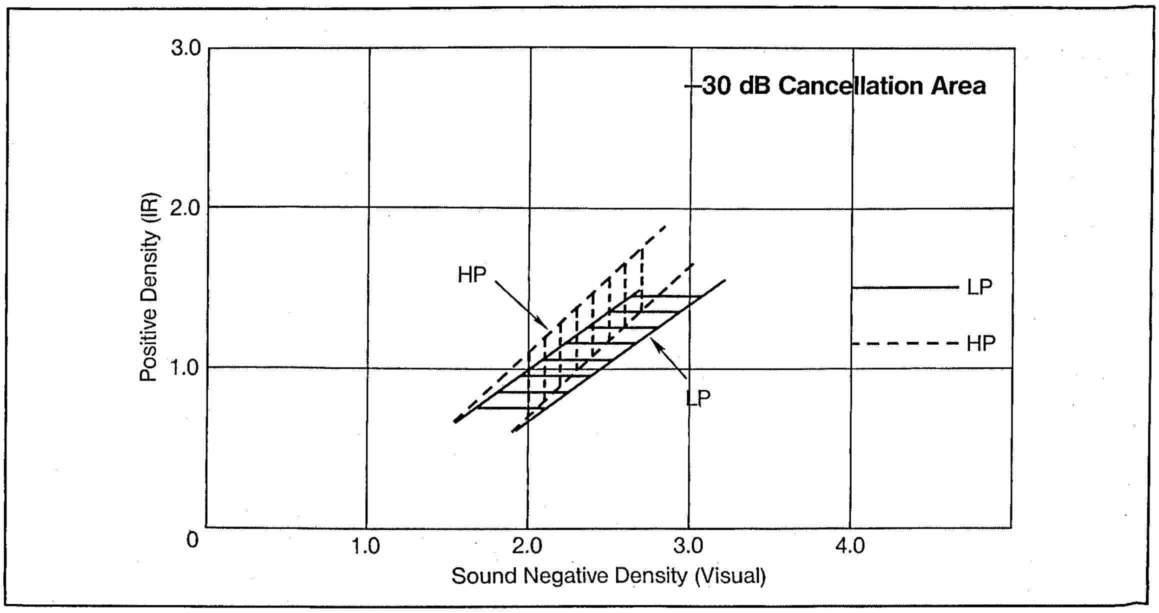

Figure 17. Cross-modulation characteristics of the Fujicolor positive films LP 8816 and HP 8814 (the oblique lines represent the area of −30 dB cancellation).