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Evaluating Color Reproduction of Medium-Speed Transparency Films

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Introduction

When was the last time you went into a professional photography store and looked at all the new color transparency films on the shelf? In recent years, Kodak has released many new EKTACHROME Films. There are currently several EKTACHROME Professional Films and one KODACHROME Professional Film in the medium speed range (ISO 64–100). Which of these films is best suited for your photography, and why?

I became interested in the inherent differences between films while preparing a dental photography presentation for the Academy of Cosmetic Dentistry in 1988. As any photographer might, I needed information about the various films available, but the type of information I could put my hands on didn't help much with the visual results from the recording process. This particular group of dentists was interested in the way different films rendered the color of the dentition and gingival tissue. It was from this early work that I became familiar with the recording characteristics of some films available at the time.

Why is it important to know about the differences in the response of films? Many photographers and others who make pictures use films indiscriminately. Often a photographer selects a film on a friend's or colleague's recommendation. The resulting photographs may be entirely adequate, but they may not be optimum for the recording task at hand.

This article is not about taking a picture, but rather about making high-quality, precise photographic records of subjects on demand. One can make such photographs with educated choices about cameras, lenses, and, of course, the best film for the situation at hand.

I find it fascinating to pick up and read a data sheet that describes films. For example, information about EKTACHROME 100 Professional Film might read, "a good general-purpose color slide film." This is obviously an understatement and it certainly doesn't tell me all I need to know to choose a film. I personally need something more specific, and I suspect that many of my colleagues do as well. Knowing how a particular film performs and having the ability to previsualize the result from using that film allows me to choose the correct film for a particular recording task.

When I am asked to photograph the subtle changes that occur to the coloration in the fibrils of an iris, I want to be reasonably certain that the film will reproduce the color with some degree of accuracy. It is no secret that some films, such as KODACHROME Film, are created with extended sensitivities. Consequently, a subject photographed using KODACHROME 64 Professional Film will be recorded differently than the same subject shot with EKTACHROME 64 Professional Film. Generally speaking, KODACHROME Films will render subjects warmer, but which film provides the most accurate representation of the subject provides some interesting issues for debate. What constitutes "better"?

Is "better" more saturation or greater fidelity? Is "better" warmer or cooler? It is important here to remember that photography in any form is only a representation of reality and not reality itself. In analyzing this question about which result is better, the answer might be "it depends." It depends on what is required, desired, or preferred in a given situation. Knowledge about the way a film works and actually seeing the result provide some insights as to what will work better and why.

Achieving an exact color can be difficult. In fact, it might be considered to be impossible by some because of the variables encountered in making a photograph. Considering the variables that influence the final results, one can understand why some experts are cynical. I am convinced that good color reproduction is possible with some hard work and reasonable awareness of the entire process. Obtaining good color quality is a fragile process.

In many cases (especially in the field of medicine), excellent color reproduction is crucial. For example, if color changes occur in skin as result of a prescribed drug treatment plan, can these changes be documented accurately with photography? What knowledge, information, and techniques must the photographer use to achieve accurate photographic documentation?

Film Characteristics

Before addressing the larger question of how to select, control, and manipulate color transparency films, let's discuss some fundamental characteristics of photographic materials. We will use parts of these definitions later in this article.

Films function the way they do because of the pre-determined characteristics that are built into the emulsions. These characteristics include:

- Sensitivity (speed)
- Grain
- Resolution
- Saturation
- Spectral Sensitivity
- Color Balance
- Neutrality
- Contrast
- Exposure Latitude
- Reciprocity

We will look at each of these characteristics briefly to interrelate films and how they function. It is difficult to analyze each characteristic alone as each directly or indirectly affects other film functions. A film's component parts are all interrelated in one way or another.

A film's sensitivity can be defined by how much energy is required to cause a response in the silver halide grains. The fewer lumens required to stimulate the silver halide in the emulsion, the higher the speed (ISO) of that film. The speed of a transparency film is defined as:

$$ISO = 1/H_m \times 10$$

where H_m = two-point average of 2.0 density above minimum density and 0.2 above minimum density (*Materials & Processes of Photography*, Stroebel, 1985).

Prior to the introduction of KODAK T-GRAIN® Emulsion technology, the sensitivity of an emulsion was modified by changing the amount of silver halide or the size of the silver halide grains used for that film; however, with tabular grain films, sensitivity is increased by flattening the grains to increase the actual surface area.

It is also useful to point out here that very strong relationships exist between some of these characteristics. For example, increasing film speed requires larger crystals or more silver halide to be used and so it can be said that higher ISO materials will have a coarser or more pronounced grain pattern.

Graininess describes the subjective impression of random unevenness observed using a grain focuser in enlargements or in other magnified images. Higher speed films typically display coarser grain while lower speed films have virtually undetectable grain. Color transparency films are classified by using an objective measurement—**diffuse RMS granularity.**

Directly related to the size and frequency of the grain is the film's ability to resolve detail. When speaking about picture elements, many make a common mistake in portraying a product as "very sharp." How sharp, though? I recently rediscovered some of my early photomicrographs that, when I made them, I believed to be really sharp. When I re-examined them, I found them quite soft by my current standards. **Sharpness** is a relative term and very subjective. Criteria changes from viewer to viewer and are contingent on experience and expectations. **Resolution** is defined as lines per millimetre reproduced on the film and is effected by contrast. Consequently, a film that resolves 100 lines/mm at a contrast ratio of 1000:1 may only resolve 50 lines/mm at 1.6:1.

Color saturation refers to a film's ability to portray color with real richness or chroma. The finer the grain, the more compact the grain structure will be, thus the higher the color saturation. Unlike the objective measurement of RMS granularity or ISO speed, saturation potentials of color films have no measurement system. Film descriptions usually contain only a reference to excellent color saturation if that information is provided at all.

Color balance is a function of the film's overall sensitivity to a particular light source with a specific color temperature. Color transparency films are balanced for either 3200K (tungsten) or 5500K (daylight); and for optimal results, the films should be exposed using light sources that match these balance aims closely. Light sources may vary from their nominal color temperature, and the photographer may need to use light balancing filters such as the KODAK WRATTEN Filters in the 81 and 82 Series.

Even subtle **color temperature** differences of light sources can affect the color of a photograph. Tungsten halogen light sources are designed to deliver 3200K over their entire life. The color temperature of a tungsten lamp changes over the life of the lamp. These changes are manifested as color shifts in slides.

Similarly, **electronic flashes** and flash tubes vary widely in color output. This may be caused by the flash tube being coated or not coated with a filter to remove UV radiation. Some diffusion materials may also influence the resulting color. It is important for critical work to test the diffusion material used over lights to ensure no changes to the color of the light as a result of what is used to diffuse it.

Spectral sensitivity deals with the specific response of each film layer to a given range of wavelengths. The visible spectrum is comprised of wavelengths ranging from 400–700 nm. A color film has three layers, each with a different sensitivity. Because each film exhibits a balance of sensitivities, different films will record different hues and achieve neutral balance differently.

KODACHROME and KODAK EKTACHROME Films have different spectral responses to subjects. If generalizations are permissible, KODACHROME Films render the world warmer with more red saturation than some EKTACHROME Films. KODAK EKTACHROME 64 Professional Film / EPR, also as a generalization, would render the subjects cooler than KODACHROME 64 Professional Film / PKR.

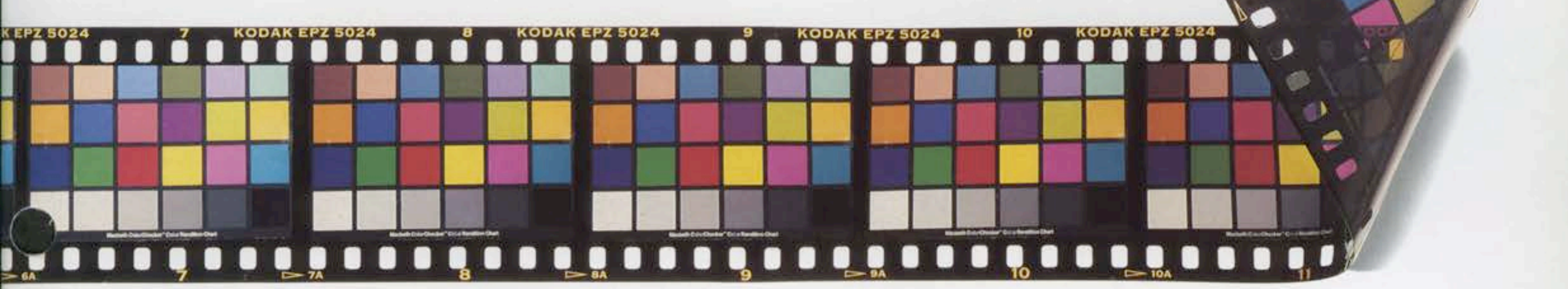
Contrast describes the basic tonal separation between highlight and shadow in a subject as recorded by the film. In color transparency films, little or no contrast control is possible other than through the use of different lighting strategies which change visual contrast of the image.

There is a slight difference in contrast when comparing EKTACHROME Films with KODACHROME Films, the latter being slightly more contrasty. The reality of the situation is that contrast is, for all intents and purposes, fixed in slide films. Push processing of some films (KODAK EKTACHROME 64T Professional Film / EPY) has been advocated for increasing contrast in photomicrography; however, it has been my experience that loss of color saturation and D-max may result from this and, consequently, offset the subtle contrast gain.

Color negative films have a wide **exposure latitude** that allows many of the point-and-shoot cameras to function as well as they do. Usable exposures can be made over a five-stop range (−2 stops, normal, +2 stops). By comparison, color transparency films allow only a narrow range of exposures, typically ± ½ stop from optimum, before critical detail is lost. As a result, very tight control of exposure is required with transparency films. The reason transparency films require such tight exposure control as compared to negative films lies in the inherent contrasts of the two film types. One can see from the characteristic curves that slide films have much greater contrast than negative color films. For this reason, a small change in exposure on slide film produces a greater density change than the same exposure change on a negative film. This for some was a boon, while for others it became a curse. With any film, process controls determine the final density, contrast, and color cast that a film will exhibit. Day-to-day and lab-to-lab fluctuations can radically change the final color.

One aspect of film choice often overlooked is **film processing.** The two processes used for current color slide films are Process E-6 (for EKTACHROME Films) and Process K-14 (for KODACHROME Films). Process E-6 allows user processing in about an hour. Process K-14 is available from a limited number of commercial laboratories. As many photographers are typically tight on deadlines, the need for quick turnaround often dictates film choice.

One popular aspect of EKTACHROME Films when they were first introduced was that the user could process them.

Exposure on the film is a product of the intensity of the image-forming light and the total time of exposure. This can be expressed by the equation

$$E = I \cdot t$$

$$\text{or Exposure} = \text{Intensity} \times \text{Time}$$

From the relationship, one can see that an exposure of 1/60 sec at *f*/8 is equivalent to an exposure of 1/30 sec at *f*/11. This relationship of exposures is known as the **law of reciprocity.**

There is, by virtue of this relationship, a range of time (controlled by shutter speed) and intensity (controlled by aperture) combinations that render the same exposure. In most situations the law holds; however, as exposures get very short (1/1000 second or less) or very long (1 second or longer), the image produced may not have the predicted density. This is called **reciprocity law failure (RLF).**

Reciprocity characteristics vary from film to film. Refer to the technical literature available for all professional transparency products to determine reciprocity information for very short or extended exposure. For example, KODAK EKTACHROME 160T Professional Film / EPT at one second acts as though it had a speed of 100 rather than the 160 rating.

Other Factors

Achieving faithful color reproduction is a challenge due to the many variables that can affect the results. There are several other factors that can affect the fidelity of the final result. These factors include:

- Different batches (emulsion number) of the same film type
- Contrast or direction of the light source
- Effect of the processing on color and density
- Exposure and resultant saturation
- Age and storage conditions of the emulsion
- Latent image keeping
- Professional and general picture-taking films

With all of these factors affecting the quality of the color-reproduction process, it is easy to see why it is sometimes difficult to get consistent color. Each of these factors, can by itself, influence the color in varying degrees.

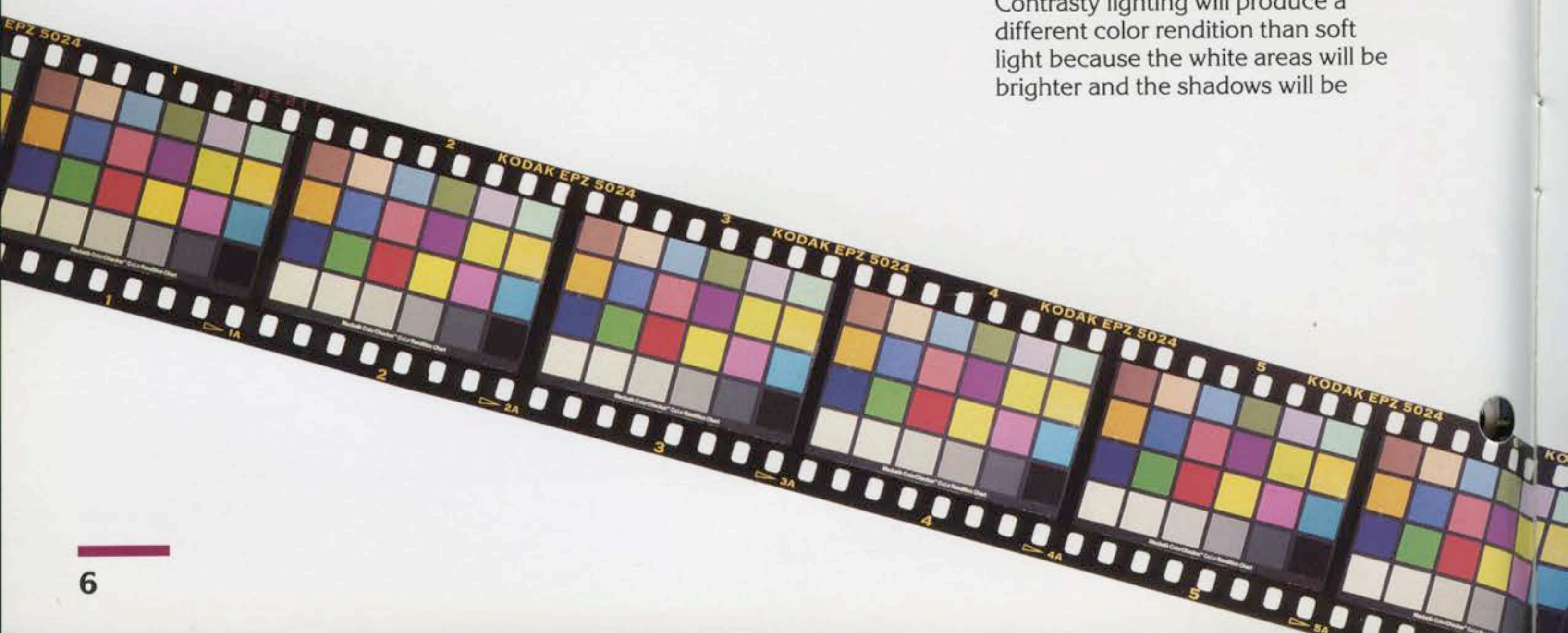
Often after the first generation original is created, post-production color balancing may take place. Adding 5CC green or removing the orange cast from a slide made with a source of the incorrect color temperature is a simple activity with slide duplicating films. In fact, with electronic photography and digital imaging, using programs such as Adobe Photoshop software, critical color is a "mouse click" away.

For the most discriminating user of silver halide films, however, post-production activities should be the last resort and not a planned activity.

Color films are manufactured in very large quantities. Each time a new batch is created, it may show slightly different characteristics. To avoid variations, it is best to use the **same emulsion number** where comparisons will be made. Determine the batch and lot number by looking at the side of a professional film box.

The **contrast** or **direction of the light source** will affect the relative brightness range between highlight and shadow. Contrasty (specular) light has a greater range of brightnesses, while softer (diffuse) light sources will have less range between the highlight and shadow. Transparency films, in general, work optimally with 80:1 brightness ratio between the usable highlight and shadow. This assumes a material with an approximate gamma of 1.8–2.0.

The contrast of the light will also affect the value or brightness of color. Contrasty lighting will produce a different color rendition than soft light because the white areas will be brighter and the shadows will be



darker. Midtones in each lighting situation are likewise affected, yielding a different appearing contrast in each case.

In a prior illustration, the concept of contrast and its effect on color was demonstrated, but equally important to color quality is density as a product of exposure. Transparency films require very tight **exposure control.** The different densities produced as a result of different exposures also effect the color saturation. Overexposed film consequently results in washed out or muted colors as compared to slightly underexposed film which results in more saturated color. For this reason and because of the inability to predict with exact certainty the color saturation in any given circumstance, it is best to bracket exposures in ⅓-stop increments over and under the predicted exposure.

One other comment about exposure and its potential role in color saturation. All contemporary films come in magazines that are DX coded. Because many of the current cameras read the DX coding, setting the ISO speed on the camera is almost a thing of the past. If you work with a DX-coded camera, make certain to read the packaged data sheet that comes with professional films and override the DX coding when necessary.

Color transparency films are integral tri-pack films. Each of the film's sensitized emulsions, red, green and blue, has a slightly different response as a function of the sensitization. As the emulsion ages, certain predictable changes occur and each emulsion will lose sensitivity. The film will undergo a color shift. An **expiration date** is an indication of usability limits. Testing of the film can confirm at what point the material no longer delivers an acceptable image and should be discarded.

Transparency films are available either as **professional** or **general picture-taking** films. Professional films are packaged close to aim for speed and color balance and are intended to be refrigerated to maintain that aim. Professionals also process their films soon after exposure. General picture-taking films are released with slightly different aims to take into account the aging common in room-temperature keeping over time before and after exposure and before processing.

Once the **latent image** has been captured, what happens next can influence the final color result. The latent image is vulnerable to changes over time. These changes can be manifested as less effective exposure, an increased density of a color slide, or changes in color saturation. The image change or loss of latent image is contingent on storage conditions, the age of the film, and the exposure to fumes from some chemicals.

The latent image is very stable for the most part. While general picture-takers may obtain adequate results with processing years after original exposure, professionals require more than merely adequate results. Some medical photographers never leave a roll of film in a camera for more than one week.

For optimum results, the film should be processed as soon as possible after exposure. Refrigeration will minimize latent-image changes.

Predictable Film Relationships

- Generally the higher the sensitivity, the more pronounced the grain pattern; the lower the ISO, the less pronounced the grain pattern. Tabular grain films may be an exception to this.
- The higher the sensitivity, the lower the resolution; while the lower the sensitivity, the higher the resolution.
- The higher the sensitivity, the lower the color saturation; while the lower the sensitivity, the higher the color saturation.
- Higher contrast films may yield pictures that appear sharper, but in reality, they have lower resolution.
- Color slide films have more contrast than color negative films; however, there is no relationship between contrast and film speed in these films. Lower-speed films may not necessarily be higher in contrast than higher-speed films.
- Color negative films can have more latitude than color slide films, but there is no relationship between latitude and sensitivity.
- Films with extended sensitivity may yield less accurate color reproduction.

Color Interpretation

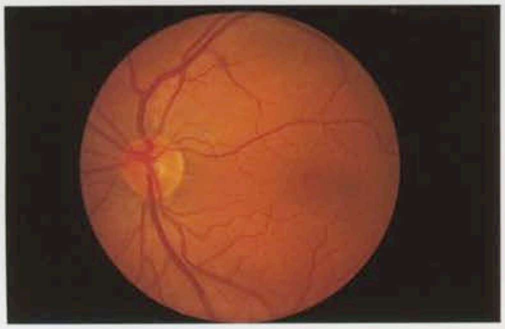
We've looked at many of the factors that affect performance of films. Now let's talk about some specific examples of images produced with several medium-speed transparency films.

We looked at examples of different subjects recorded on seven color transparency films. The films are:

KODACHROME 64 Professional Film / PKR
KODAK EKTACHROME 64 Professional Film / EPR
KODAK EKTACHROME 64T Professional Film / EPY
KODAK EKTACHROME 64X Professional Film / EPX
KODAK EKTACHROME 100 Professional Film / EPN
KODAK EKTACHROME 100 PLUS Professional Film / EPP
KODAK EKTACHROME 100X Professional Film / EPZ

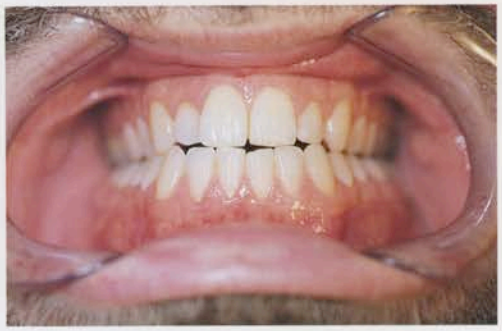
① KODAK EKTACHROME 100 Professional Film / EPN. This film was judged most neutral. Other films also produced pleasing results.

② KODAK EKTACHROME 100 PLUS Professional Film / EPP. This film showed neutral reproduction and excellent saturation.

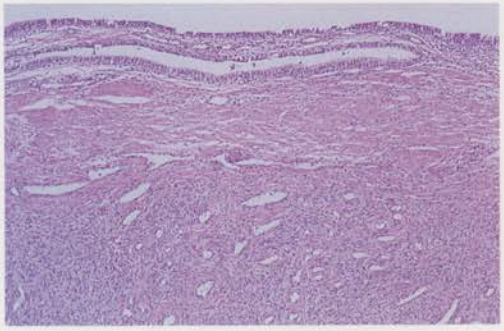


③ KODACHROME 64 Professional Film / PKR. While all films provided good results, this film showed the highest degree of discrimination.

④ KODAK EKTACHROME 64X Professional Film / EPX. This film showed the highest degree of separating ability with this subject.



⑤ KODAK EKTACHROME 64 Professional Film / EPR. This film produced neutral images with excellent saturation.



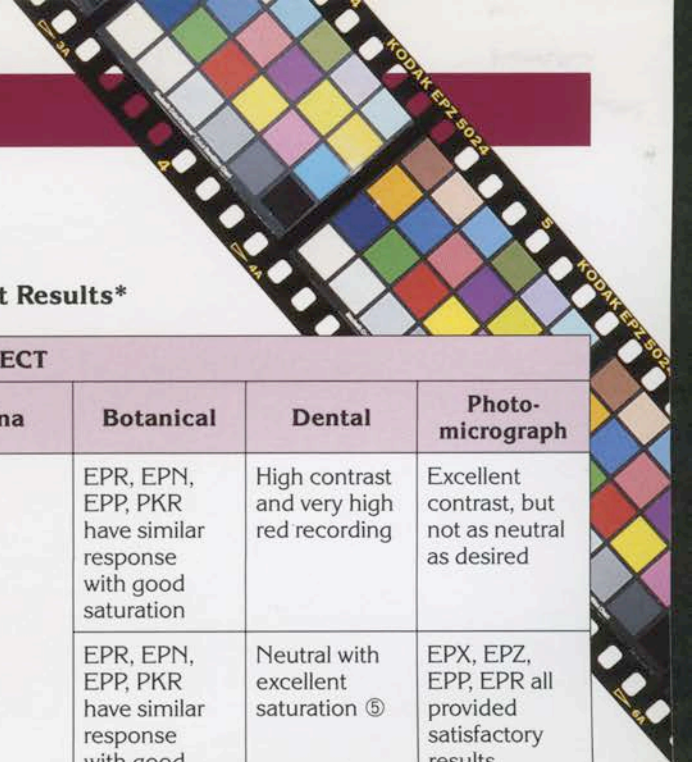
⑥ KODAK EKTACHROME 64T Professional Film / EPY. This film showed the most accurate rendition of the H&E stain using a didymium filter.

In pursuing this research, we chose and evaluated many subjects that reflect those typically encountered in the life sciences. This is the area in which I work. It is by no means a complete evaluation, but it does adequately represent a sizable amount of work for comparative results. The subjects included:

- Color checker/gray card
- Flesh tone
- Iris/eye
- Retina
- Botanical
- Dental
- Photomicrograph

The images were produced under the tightest possible controls. All emulsions were kept frozen prior to use and were re-frozen after exposure until they were processed. All films were processed at the same time to eliminate color shifts due to processing variations. In each series, the light source, camera, lens, and procedures were consistent in an attempt to allow the film itself to be the only difference that is presented as a final result.

Here are some of my impressions of the performance of these films with the various subjects. I assessed all transparencies using a Macbeth D5500 standard transparency viewer. My judgments are based on my experience with the demands of scientific records.



Visual Assessment of Test Results*

KODAK Film	SUBJECT: Color Checker/ Gray Card	Flesh Tone	Iris/eye	Retina	Botanical	Dental	Photo-micrograph
KODACHROME 64 Professional PKR	Good overall check of rendition of individual colors, but should not be used to make a final judgment for a critical use in scientific recording	Too much contrast and red recording	Too much contrast and red recording	All films provided good results; however, there was considerable deviation in density. PKR seems to provide the highest degree of discrimination. ③	EPR, EPN, EPP, PKR have similar response with good saturation	High contrast and very high red recording	Excellent contrast, but not as neutral as desired
EKTACHROME 64 Professional EPR		Very pleasing result, warmer than other films	Neutral with excellent saturation in low-contrast subject		EPR, EPN, EPP, PKR have similar response with good saturation	Neutral with excellent saturation ⑤	EPX, EPZ, EPP, EPR all provided satisfactory results
EKTACHROME 64T Professional EPY		• With 85B, slight exposure error with resulting decrease in saturation • With tungsten, jaundice-like flesh tone	With 85B, slight exposure error and increased yellow response		With 85B, enhanced warmth with good saturation	• Neutral with excellent saturation • With 85B, very warm with low saturation	Most accurate rendition of H&E stain using a didymium filter ⑥
EKTACHROME 64X Professional EPX		Very pleasing result, increased saturation and red enhancement	Good saturation, but warmer and effectively lower blue recording		Highest degree of separating ability ④	Excellent saturation, but warmer image recording	EPX, EPZ, EPP, EPR all provided satisfactory results
EKTACHROME 100 Professional EPN		Most neutral ①	Neutral with excellent saturation in low-contrast subject		EPR, EPN, EPP, PKR have similar response with good saturation	Neutral with excellent saturation	With 80A, provided interesting discriminating ability
EKTACHROME 100 PLUS Professional EPP		Very pleasing result, increased saturation and red enhancement	Neutral with excellent saturation in low-contrast subject ②		EPR, EPN, EPP, PKR have similar response with good saturation	Excellent saturation, but reds noticeably enhanced	EPX, EPZ, EPP, EPR all provided satisfactory results
EKTACHROME 100X Professional EPZ		Very pleasing result, increased saturation and red enhancement	Good saturation, but warmer and effectively lower blue recording		Highest degree of separating ability	Excellent saturation, but warmer image recording	EPX, EPZ, EPP, EPR all provided satisfactory results

*All transparencies were visually assessed using a Macbeth D5500 standard transparency viewer.

Personal Note

It was my hope with this project to provide other working professionals with help in selecting films for their needs. By no means is any of this work meant to misrepresent the performance of any film.

In many cases procedures were used that might not reflect traditional approaches; however, data was the objective. In all electronic-flash applications, EKTACHROME 64T Professional Film was exposed using a KODAK WRATTEN Light Balancing Filter No. 85B. This is an acceptable practice, although in some cases, it was additionally exposed to tungsten illumination. This provides a more optimal match of light to film in an attempt to avoid distorting the data.

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Acknowledgments

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