Exposure Metering
Relating Subject Lighting to Film Exposure
By Jeff Conrad

A photographic exposure meter measures subject lighting and indicates camera settings that nominally result in the best exposure of the film. The meter calibration establishes the relationship between subject lighting and those camera settings; the photographer's skill and metering technique determine whether the camera settings ultimately produce a satisfactory image.

Historically, the "best" exposure was determined subjectively by examining many photographs of different types of scenes with different lighting levels. Common practice was to use wide-angle averaging reflected-light meters, and it was found that setting the calibration to render the average of scene luminance as a medium tone resulted in the "best" exposure for many situations. Current calibration standards continue that practice, although wide-angle average metering largely has given way to other metering techniques.

In most cases, an incident-light meter will cause a medium tone to be rendered as a medium tone, and a reflected-light meter will cause *whatever is metered* to be rendered as a medium tone. What constitutes a "medium tone" depends on many factors, including film processing, image postprocessing, and, when appropriate, the printing process. More often than not, a "medium tone" will not exactly match the original medium tone in the subject. In many cases, an exact match isn't necessary—unless the original subject is available for direct comparison, the viewer of the image will be none the wiser.

It's often stated that meters are "calibrated to an 18% reflectance," usually without much thought given to what the statement means. Will metering an 18% reflectance ensure a "correct" exposure? Is an 18% reflectance rendered as an 18% reflectance in a print? How would this apply to an image that is projected or viewed on a computer monitor rather than printed? In any event, meter calibration has nothing to do with reflectance. A reflected-light meter is aimed at a target of known luminance and adjusted to give an appropriate reading; similarly, an incident-light meter is exposed to a point source of known illuminance and adjusted.[1]

Subject Luminance Range

Almost any subject of photographic interest contains elements of different luminance; consequently, the "exposure" actually is many different exposures. The shutter time is the same for all elements, but the image illuminance varies with the luminance of each subject element. The *subject luminance range* (SBR)[2] is the difference, in exposure steps, between the brightest and darkest parts of the subject. An SBR of 7 exposure steps usually[3] is considered "normal" for a sunlit outdoor scene; the SBR depends on two factors:

- The reflectances of the subject elements. The reflectance of natural objects varies from approximately 4% to 90%, a 4.5-step range. It's unusual for a subject to encompass the entire range, especially the lower end, so a range of 4 steps is more typical.

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- The subject illuminance range, typically 2–4 steps. Illuminance in areas of open shade typically is about 2–3 steps less than in sunlight; areas in deep shade can be considerably darker. An illuminance range of 3 steps is considered normal[4] for a sunlit outdoor scene.

Because different parts of a typical subject receive different illumination, the concept of average subject reflectance isn't always meaningful. Estimates of the "effective" average reflectance of a typical sunlit outdoor scene (taking varying illumination into account) range from about 12% to 20%, but this doesn't directly relate to the reflectance of any element in the scene. It probably is more instructive to examine the effects of exposure on individual subject elements.

If a subject with a 4.5-step reflectance range were uniformly illuminated, an element with 90% reflectance would be given 2.3 steps greater exposure than an element with 18% reflectance. Similarly, an element with 4% reflectance would be given 2.17 steps less exposure than the 18% reflectance. If a meter reading were made of the 18% reflectance, the overall exposure on most films probably would be acceptable, although there might be a slight loss of highlight detail with color reversal film.

If the same subject contained shadow areas that received 2.5 steps less illuminance than the sunlit areas, an element with 9% reflectance in a shadow area would get 3.5 steps less exposure than a sunlit element with 18% reflectance, and would record as featureless black. If the exposure were increased by 1 step, some detail might be retained in the 9% shadowed area, but the exposure of the sunlit areas also would increase. With negative films, this exposure probably would retain adequate highlight detail; with black-and-white sheet film, the development could be reduced to expand the usable exposure range and perhaps tolerate even additional exposure. With color reversal film, however, the exposure could not be increased without loss of highlight detail. Because washed-out highlights usually are more objectionable than loss of shadow detail, the best exposure for color reversal film probably would be based on the sunlit 18% reflectance.

Subject Luminance Distribution

An averaging reflected-light meter responds only to overall average luminance, and cannot distinguish between a subject of uniform luminance and one that consists of light and elements. If the part of a scene that is metered includes large areas of unusually high or low reflectance, or unusually large areas of highlight or shadow, the "effective" average reflectance may differ substantially from "normal," and the rendering may not be what is desired. In such a situation, some exposure adjustment or alternative metering techniques may be required.

It's not always obvious what constitutes a "normal" luminance distribution, even in a simple case for which the subject illuminance is uniform. Consider a chessboard for which the white squares have a reflectance of 90% and the black squares a reflectance of 4%; if the illuminance is uniform, the luminance range depends only on reflectance. The midpoint of the 4.5-step reflectance range would correspond to approximately 19% reflectance:

$$\text{Luminance range} = \log_2 \frac{0.90}{0.04} = \log_2 22.5 = 4.49$$

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$$\text{Midpoint reflectance} = \frac{0.90}{2^{2.25}} = 0.1897$$

If necessary, the base-2 logarithm can be computed from

$$\log_2 a = \frac{\log a}{\log 2} = \frac{\ln a}{\ln 2}$$

The reflectances of the white and black squares would be 2.25 exposure steps above and below the midpoint.

A chessboard with a single white square, one with a single black square, and a normal chessboard with equal numbers of black and white squares all would have the same luminance range, and would require the same exposure for proper tonal rendering. An all-white chessboard would have only a single luminance, but still would require the same exposure as the other boards for proper rendering of the white. This requirement becomes especially obvious if all chessboards appear in the same photograph.

A reflected-light reading of an 18% reflectance in the same position as any of the chessboards probably would indicate a reasonable exposure, as would an incident-light reading. However, wide-angle average reflected-light readings of each of the chessboards would indicate different exposures, and none of the indicated exposures likely would be correct.

For the all-white board, a reflected-light reading would indicate an exposure that would render the board as middle gray, the same as would happen with a board of midpoint reflectance, despite the 2.25-step difference in reflectance.

It's often thought that a normal scene contains an equal number of light and dark areas. This simply isn't true if the light and dark areas constitute a significant fraction of the subject: a 50% reduction in luminance is one exposure step. The average reflectance for the normal chessboard would be

$$0.5 \times 0.90 + 0.5 \times 0.04 = 0.47$$

The difference in reflectance, in exposure steps, from that of the white squares would be

$$\log_2 \frac{0.47}{0.90} = \log_2 0.522 = -0.94$$

The indicated exposure would render the average reflectance of 47% as a medium gray, even though no element in the image actually would be medium gray. That exposure would be approximately one step greater than that for the all-white board, and would render the white squares as light gray and the black squares as nearly black.

The fraction w of white squares that would give an average reflectance equivalent to the 19% midpoint reflectance can be found from

$$0.90w + 0.04(1 - w) = 0.1897$$

$$0.86w = 0.1497$$

$$w = 0.1741$$

or $0.1741 \times 64 = 11.14$ white squares. It should be obvious that light areas dominate wide-angle reflected light measurements.

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Dependence on normal luminance distribution can be avoided by making reflected-light measurements of the individual white and black squares. This task is easier when using a narrow-angle reflected-light meter, commonly known as a spotmeter.

Averaging individual reflected-light measurements works well when the areas measured are approximately equally brighter and darker than a medium tone, as would be the case with a chessboard, but less well otherwise. Moreover, rendering the average luminance as a medium tone does not ensure that the lightest and darkest elements of the subject will be within the film's exposure range.

Many cameras incorporate multi-segmented metering that makes separate measurements of different parts of the subject, and sets exposure based on comparison of luminance distribution with statistical data compiled from many types of images. For subjects with unusual luminance distribution, multi-segmented metering often gives better results than wide-angle averaged metering, but results depend on how the different metering segments align with the different subject elements.

The Two-Minute Zone System

In the early 1940s, Ansel Adams and Fred Archer devised the Zone System, in which measurements are made of individual subject elements, and exposure is adjusted based on the photographer's knowledge of what is being metered: a photographer knows the difference between freshly fallen snow and a black horse, while a meter does not. Volumes have been written on the Zone System, but in essence, the concept is very simple—render light subjects as light, and dark subjects as dark. The Zone System assigns numbers from 0 through 9 to different brightness values, with 0 representing black, 5 middle gray, and 9 white. To make zones easily distinguishable from other quantities, Adams and Archer used Roman rather than Arabic numerals. Strictly speaking, zones refer to exposure, with a Zone V exposure (the meter indication) resulting in a mid-tone rendering in the final image. Each zone differs from the preceding zone by a factor of two, so that a Zone I exposure is twice that of Zone 0, and so forth. A one-zone change is equal to one exposure step, corresponding to standard aperture and shutter controls on a camera.

Many cameras incorporate provision for exposure compensation; the relationship between exposure zones and exposure compensation is shown in Table 1.

Table 1. Exposure Zones and Exposure Compensation

Zone	Exp. Comp.	Characteristic
0	–5	Pure black
I	–4	
II	–3	
III	–2	Darkest tone with detail
IV	–1	
V	**+0**	Middle gray (meter indication)
VI	+1	
VII	+2	Lightest tone with detail
VIII	+3	
IX	+4	Pure white

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For example, a subject slightly lighter than normal might be given a Zone VI exposure ("placed" on Zone VI), and would be rendered slightly lighter than a middle tone with normal printing. Such an exposure would be equivalent to +1 exposure compensation.

Black-and-white film typically maintains detail for shadows placed on Zone III or higher, and for highlights placed on Zone VII or lower. For color reversal film, detail is usually maintained between Zones IV and VII, with the detail becoming faint in Zone VII.

With black-and-white sheet film, for which the Zone System originally was devised, each negative can be processed individually, and development can be adjusted to control the contrast. With roll film, especially color, contrast control usually isn't possible. Accordingly, exposure must be chosen for one subject element, and the other elements then "fall" where they will. For example, if a rising moon were photographed on color reversal film, and the contrast between the foreground and the moon was four steps, the exposure would need to favor either the moon or the foreground. If the foreground were placed on Zone IV, the moon would fall on Zone VIII, and would loose nearly all detail. If the moon were placed on Zone VII to retain a hint of detail, the foreground would fall on Zone III, and most shadow detail would be lost.

Adams described the Zone System in numerous books, most recently in *The Negative* (1981)[5]. Some photographers were intimidated by the purported complexity of the Zone System; Fred Picker (1974)[6] described very simple methods for determining effective film speed and development time. In addition, Picker determined film development time based on a print tone slightly lighter than pure white (the original Zone System determined development based on a medium tone), ensuring that the brightest and darkest elements of the subject would be within the exposure scale of the paper. Phil Davis (1981)[7] described systematic, rigorous testing of paper and film to match film exposure and development to the paper's exposure scale. Additionally, Davis included a method to achieve essentially the same results with incident-light measurements.

Relationship of Subject Luminance to Film Exposure

For a subject of uniform luminance, exposure at the film plane of a camera is given by

$$H_\mathrm{f} = E_\mathrm{f} t \tag{1}$$

where

E_f = Film plane illuminance in lx

H_f = Film plane exposure in lx·s

t = Effective shutter time in s

The shutter time is determined by the "shutter speed" setting; film plane illuminance is determined by the lens aperture, and is given by

$$\begin{aligned} E_\mathrm{f} &= TFV\left(1-\frac{f}{u}\right)^2 \cos^4\theta \frac{\pi}{4}\frac{L_\mathrm{s}}{N^2} \\ &= \frac{bL_\mathrm{s}}{N^2} \end{aligned} \tag{2}$$

where

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b = Constant with units of $\mathrm{lx \cdot cd^{-1} \cdot m^2}$
θ = Angle between subject and lens axis
N = Relative aperture (f-number) of lens
F = Lens flare correction factor
f = Focal length of lens in m
V = Lens vignetting factor
L_s = Luminance of subject in $\mathrm{cd \cdot m^{-2}}$
T = Lens transmittance factor
u = Subject distance in m

ANSI PH3.49-1971[8] assumed $F = 1.03$, $T = 0.90$, and $V = 1.0$ as representative values for lens performance. To simplify exposure determination for the casual photographer, that standard also assumed a subject 12° from the lens axis at a distance $u = 80f$, so that

$$\cos^4 \theta = 0.916$$

and

$$\left(1 - \frac{f}{u}\right)^2 = 0.975$$

giving a value of $b = 0.650$[9]. The correction for the lens extension assumed here is minimal, but in some situations, such as close-up photography, the correction can be substantial.

It may be easier for the serious photographer to start with a subject on the lens axis at infinity, and make corrections for subject position and lens extension if required. The starting values then become

$$\cos^4 \theta = 1$$

$$\left(1 - \frac{f}{u}\right)^2 = 1$$

and $b = 0.728$. Of course, a camera with a meter that measures through the taking lens automatically responds to the effect of lens extension, so that no additional correction is needed.

Exposure Meter Calibration

Reflected-Light Meters

A reflected-light exposure meter indicates aperture and shutter speed settings based upon subject luminance. The relationship between indicated camera settings and scene luminance is

$$2^{EV} = \frac{N^2}{t} = \frac{L_s S}{K} \tag{3}$$

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where *EV* is the *exposure value*, *S* is the arithmetic ISO speed, and *K* is the meter calibration constant. The exposure H_g that results from setting the camera according to the meter indication then is

$$H_{\mathrm{g}} = E_{\mathrm{f}} t = b L_{\mathrm{s}} 2^{-EV} = \frac{bK}{S} \tag{4}$$

Nominal calibrations differ slightly from manufacturer to manufacturer. The range of values for *K* recommended by ANSI/ISO 2720-1974[1] is 10.6 to 13.4; in practice, values of 12.5 (Canon, Nikon, and Sekonic) or 14 (Minolta and Pentax) are common. The difference between the values of 12.5 and 14 is approximately 0.16 step, which is less than most meter manufacturers' calibration tolerances. If two meters from different manufacturers indicate substantially different exposures for the same subject, it's probably not because of differences in the manufacturers' calibrations.

In the late 1970s, there was a brief controversy regarding the use of calibration constants for exposure meters. Ansel Adams lamented[10] that some manufacturers "depart from standard calibration of their meters by incorporating a 'K factor,'" with the result that "if we make a careful reading from a middle-gray surface, the result will not be exactly a middle gray!" Although Adams acknowledged the tendency of average readings of a subject to produce slight underexposure, he continued, ". . . I find it far preferable to work with what I consider to be the true characteristics of the light and the films. Intelligent use of the meter eliminates the need for such artificial aids as the K factor." At that time, the calibration equation often was given as

$$\frac{N^2}{t} = L_{\mathrm{s}} S$$

The apparent lack of a "K factor" in the calibration equation[11] arose from the United States' dogged eschewal of metric practice: it was common to express luminance in $\mathrm{cd \cdot ft^{-2}}$, even though film speed was expressed in SI (metric) units. When luminance was expressed in $\mathrm{cd \cdot m^{-2}}$ for consistency with the other variables, the formula became

$$\frac{N^2}{t} = \frac{L_{\mathrm{s}} S}{10.76}$$

with the "K factor" of 10.76 arising from the conversion of $\mathrm{m^2}$ to $\mathrm{ft^2}$. It should be apparent that the *K* of 10.76, rather than arising from a natural law, was an arbitrary choice, determined from what viewers determined to be the "best" exposures. The question, then, was not whether to use a "K factor," but rather, what its value should be. Because of slight changes in the methods for determining film speeds, ANSI PH3.49-1971 increased the recommended value to 1.16 (or 12.5 when luminance was expressed in $\mathrm{cd \cdot m^{-2}}$). The ANSI/ISO 2720-1974 recommends a range of 10.6 to 13.4.

The controversy regarding the use of the "K factor" appears to have faded, although Adams's advocacy of intelligent use of the meter is as valid now as it was then.

Incident-Light Meters

An incident-light meter relates camera settings to subject illuminance; the relationship is

$$2^{EV} = \frac{N^2}{t} = \frac{E_s S}{C} \tag{5}$$

With a flat-disc (cosine-response) receptor, the range of values for C recommended by ANSI/ISO 2720-1974 is 240 to 400, with 250 a common choice of meter manufacturers. With a hemispherical (cardioid-response) receptor, the recommended range of values for C is 320 to 540; values toward the lower end of the range are common.

Comparison of Reflected- and Incident-Light Meters

The *luminous exitance* M_s is the luminous flux reflected or emitted by a surface; reflectance ζ is the ratio of luminous exitance to illuminance E_s:

$$M_s = \zeta E_s \tag{6}$$

For a flat, perfectly diffuse, front-lighted subject, the luminance L_s is related to the luminous exitance by

$$L_s = \frac{M_s}{\pi} \tag{7}$$

Luminance then is related to illuminance by

$$L_s = \frac{\zeta E_s}{\pi} = \rho E_s \tag{8}$$

where ρ is the *luminance coefficient*.

Comparing a reflected-light meter to an incident-light meter,

$$\frac{L_s S}{K} = \rho \frac{E_s S}{K} = \frac{E_s S}{C} \tag{9}$$

and the reflectance is

$$\zeta = \pi\rho = \pi \frac{K}{C} \tag{10}$$

Illuminance is measured with a flat-disc receptor; an incident-light meter using a flat-disc receptor with a C of 250 would indicate the same exposure as a reflected-light meter with a K of 12.5 measuring a flat subject with a reflectance of 15.7% ($\rho = 0.050\ \mathrm{cd \cdot m^{-2} \cdot lx^{-1}}$). This might suggest that the meters are "calibrated to a 16% reflectance," although this really describes only the relationship between the incident- and reflected-light meters. If the values for C and K were doubled, the meters also would indicate the same exposure when reading a flat 16% reflectance, but the indicated exposure would double. ANSI/ISO 2720-1974 does not suggest a relationship between K and C, and does not suggest that either relate to any specific average subject reflectance, merely directing that

> "The constants K and C shall be chosen by statistical analysis of the results of a large number of tests carried out to determine the acceptability to a large number of observers, of a number of photographs, for which the exposure was known, obtained under various conditions of subject manner and over a range of luminances."

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Typical photographic subjects aren't flat, and the light source often isn't directly behind the camera. Experience has shown that a hemispherical receptor usually gives better results for incident-light readings in practical picture-taking situations, integrating the effect of lighting from different sources at different angles on three-dimensional objects. In most such situations, however, it is difficult to develop a simple relationship such as Equation (10) between the reflected- and incident-light measurements.

Effect of Meter Calibration—Reflected-Light Meters

The effect of most reflected-light meter calibrations is to give whatever is metered an exposure somewhere near the middle of a film's exposure range, although it's seldom at the exact midpoint. If the area metered is close to a medium reflectance, the exposure for that area usually will be satisfactory. The greater problem usually is in getting satisfactory exposure for light and dark areas. The effect of meter calibration on light and dark elements of a subject perhaps is best visualized by superimposing those exposures on the film's characteristic curve.

For users of the Zone System, the exposure given to a subject element placed on Zone z is

$$H_z = \frac{bK}{S} 2^{z-5} \tag{11}$$

The results of this are shown for typical black-and-white negative, color negative, and color reversal films.

Black-and-White Negative Film

The ISO speed[12] for black-and-white negative film is based on an exposure H_m that results in a net density in the negative of 0.1, and is given by

$$S = \frac{0.8}{H_\mathrm{m}}$$

so that

$$H_\mathrm{g} = \frac{bK}{S} = \frac{bK}{0.8} H_\mathrm{m} \tag{12}$$

For an on-axis subject at infinity focus, with $b = 0.728$ and $K = 12.5$, the exposure that results is

$$H_\mathrm{g} = \frac{bK}{0.8} H_\mathrm{m} = 11.38 H_\mathrm{m} \tag{13}$$

or, in exposure steps,

$$\log_2 H_\mathrm{g} = \log_2 H_\mathrm{m} + 3.51 \tag{14}$$

ANSI/ISO 6-1993 specifies a higher contrast than usually is desired for practical photographic use. Consequently, photographers often use different processing, and the *effective film speed* may be different from the ISO speed. However, if, except for the contrast, the

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method used to determine the speed is similar, the above relation often can be used if the ISO film speed is replaced with the effective film speed.

It’s common for photographers who use the Zone System to determine effective film speed by requiring that a Zone I exposure (four steps less than meter indication) produce the same 0.1 net density specified in the ISO standard. Consequently, effective film speed determined in this manner will be approximately 0.5 step less than the ISO speed. If the film is developed to a lower contrast, as often is the case, the difference between ISO speed and effective speed may be even greater.

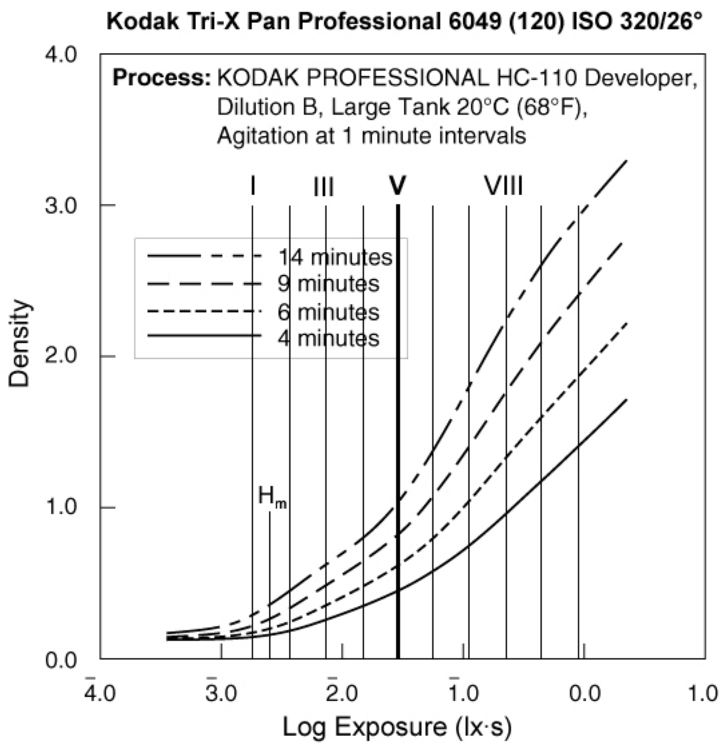

Figure 1. Characteristic Curve and Exposure Zones for Black-and-White Negative Film

The zone exposures are based on the ISO speed of 320; the 6-minute development time is closest to “normal.” If the Zone I exposure were required to yield the threshold density of 0.1 above film base + fog, the zone exposures would shift to the right by 0.5 exposure step (0.16 log *H*), and development probably would be slightly reduced.

Typical of modern black-and-white films, this film has considerable usable exposure range to the right of the indicated (Zone V) exposure, so the best exposure of a subject with a wide SBR probably would favor shadow detail, while still allowing acceptable recording of highlight detail. Tone reproduction is only one element of a good image, however. Figure 1 suggests that highlight detail would be maintained even if exposure were increased by 2–3 steps, but increased exposure increases grain and slightly reduces sharpness. Moreover, a denser negative usually is more difficult to print. The best exposure usually is the minimum exposure that gives adequate shadow detail.

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Color Negative Film

The ISO speed[13] for color negative film is based on a minimum-density exposure and is given by

$$S = \frac{\sqrt{2}}{H_{\mathrm{m}}}$$

so that

$$H_{\mathrm{g}} = \frac{bK}{\sqrt{2}} H_{\mathrm{m}} \tag{15}$$

With $b = 0.728$ and $K = 12.5$, the exposure that results is then

$$H_{\mathrm{g}} = \frac{bK}{\sqrt{2}} H_{\mathrm{m}} = 6.43 H_{\mathrm{m}} \tag{16}$$

or, in exposure steps,

$$\log_2 H_{\mathrm{g}} = \log_2 H_{\mathrm{m}} + 2.69 \tag{17}$$

The ISO standard specifies the film manufacturer's normal processing, so that the effective film speed usually is very close to the ISO speed.

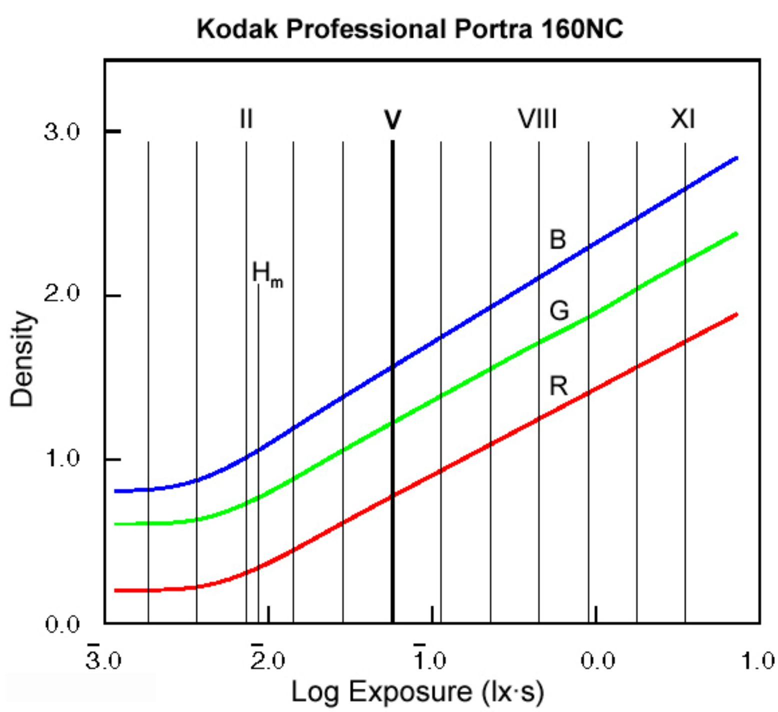

Figure 2. Characteristic Curve and Exposure Zones for Color Negative Film

This film has greater usable exposure range to the right of the indicated (Zone V) exposure than to the left, so it is quite tolerant of moderate overexposure. The best exposure of a subject with a wide SBR probably would favor shadow detail.

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Color Reversal Film

The ISO speed for color reversal film[14] is based on a mid-tone exposure and is given by

$$S = \frac{10}{H_\mathrm{m}}$$

With the same values for b and K, the resulting exposure is

$$H_\mathrm{g} = \frac{bK}{10} H_\mathrm{m} = 0.91 H_\mathrm{m} \tag{18}$$

or, in exposure steps,

$$\log_2 H_\mathrm{g} = \log_2 H_\mathrm{m} - 0.14 \tag{19}$$

The exposure will be near the middle of the exposure range for most color reversal films. The ISO standard specifies the film manufacturer's normal processing, so that the effective speed for most color reversal films is very close to the ISO speed.

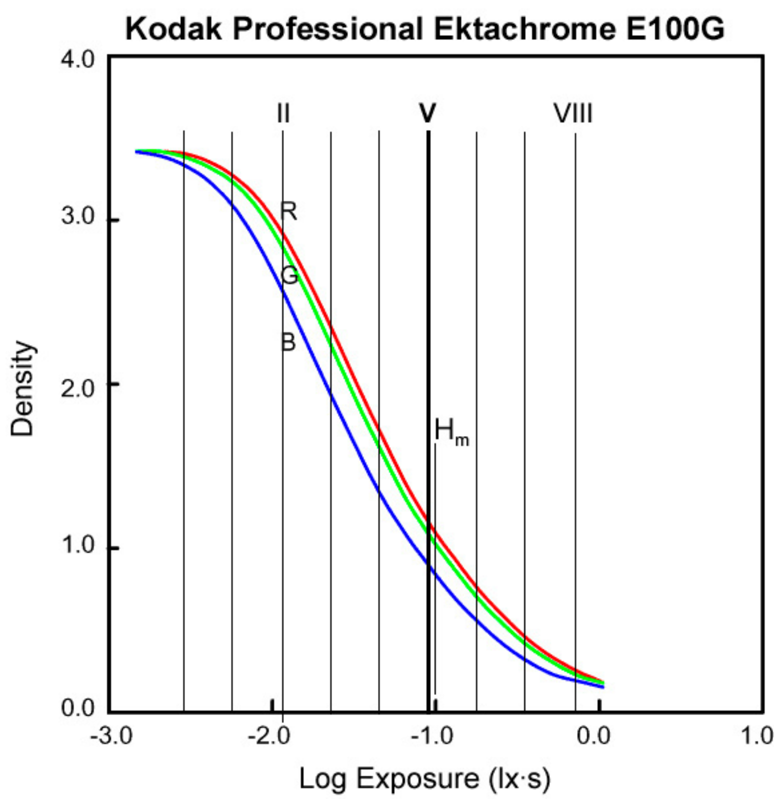

Figure 3. Characteristic Curve and Exposure Zones for Color Reversal Film

Typical of color reversal films, the exposure range is limited, especially to the right of the indicated (Zone V) exposure. Detail may be lost in any area given exposure at Zone VII or above, so the best exposure normally should favor the highlights. Substitute metering of an 18% neutral test card in a subject with many light areas may result in loss of highlight detail unless the indicated exposure is reduced by 0.5 to 1 step as indicated in the Kodak instructions.

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Usable contrast extends to Zone II, but under traditional viewing conditions, detail may be difficult to discern because of the high density. With contrast masking, however, some of this detail can be recovered. The advent of digital postprocessing greatly simplifies such a task, and gives color photographers some of the flexibility previously available only to large-format black-and-white photographers.

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Notes

[1] ANSI/ISO 2720-1974 (R1994), General Purpose Photographic Exposure Meters (Photoelectric Type)—Guide to Product Specification (New York: American National Standards Institute, 1994).
[2] Originally, “subject brightness range.” Brightness, however, properly refers to the subjective impression of luminance. Although used by some authors, “SLR” invites confusion with “single lens reflex,” so “SBR” has persisted.
[3] Hollis Todd and Richard Zakia, *Photographic Sensitometry: The Study of Tone Reproduction*, 7 (Dobbs Ferry, NY: Morgan and Morgan, Inc, 1969), suggest a range of 160:1, or about 7.32 exposure steps.
[4] Phil Davis, *Beyond the Zone System*, 4th ed. (Boston: Focal Press, 1999), suggests a range of two steps, in conjunction with a 5-step reflectance range.
[5] Ansel Adams, *The Negative* (Boston: New York Graphic Society, 1981).
[6] Fred Picker, *Zone VI Workshop: The Fine Print in Black & White Photography* (Garden City, N.Y., Amphoto, 1974).
[7] Davis, *Beyond the Zone System* (New York: Curtin & London, 1981).
[8] ANSI PH3.49-1971, after several revisions, was redesignated as ANSI/ISO 2720-1974 (R1994). Unfortunately, the explanatory appendixes no longer are included.
[9] This value is used in several ISO standards that relate object luminance to film-plane illuminance.
[10] *The Negative*, 42–43.
[11] Actually, ANSI PH2.12-1961 recommended a K of 1.06 when the luminance was expressed in $\mathrm{cd \cdot ft^{-2}}$. ANSI PH3.49-1971 increased this value to 1.16 to accompany changes in methods for determining film speeds.
[12] See ANSI/ISO 6-1993, Photography—Black-and-White Pictorial Still Camera Negative Film/Process Systems.
[13] See ANSI PH2.27-1979, Method for Determining the Speed of Color Negative Films for Still Photography. Note: this standard has been superseded by ANSI/ISO 5800-1987 (R1994), Photography—Color Negative Films for Still Photography—Determination of ISO Speed.
[14] ANSI PH2.21-1979, Method for Determining the Speed of Color Reversal Films for Still Photography). Note: this standard has been superseded by ANSI/ISO 2240-1994, Photography—Color Reversal Camera Films—Determination of ISO Speed.

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