Average Scene Reflectance in Photographic Exposure Metering

Douglas A. Kerr, P.E.

Issue 1
January 30, 2005

ABSTRACT

The quantity "assumed average scene reflectance" is widely mentioned in connection with the calibration of "reflected light" photographic meters. Understanding of its significance is elusive. In this paper, we examine the actual significance of this quantity and how it plays a role in deciding upon a calibration constant for a reflected-light exposure meter. We also examine the significance of various oft-mentioned values of assumed average scene reflectance, such as 18% and 12-13%, and finally discuss the use of a gray card of known reflectance to perform "incident light" metering using a reflected light meter.

SUMMARY

The quantity "assumed average scene reflectance" is widely mentioned in connection with the calibration of "reflected light" photographic meters. Often questions are raised as to exactly what that means, and as to what numerical value has likely been used in establishing a calibration for a particular exposure meter or in-camera metering system.

Also of interest is the matter of using a "gray card" target to perform incident light metering with a reflected light meter. The question is often raised as to what reflectance is most appropriate for direct use of such a card.

We conclude that:

- The matter of the significance of the average scene reflectance assumed in the calibration of a reflected light meter is not a simple one.

- The value of assumed average reflectance of a "typical" scene upon which the calibration of reflected light meters is predicated is commonly 18%. However, in order to provide margin against overexposure in cases where the actual average scene reflectance is less than the assumed average, the numerical value of assumed average scene reflectance actually used to choose a meter calibration factor is commonly in the range 12%-13%.

- Thus statements that "the metering calibration is based on an assumed average scene reflectance of 18%" and "the metering calibration is based on an assumed average scene reflectance of 12%-13%", presented without further elaboration, can both be considered true for the same meter.

- The most appropriate reflectance for a "gray card" to be used directly for incident light metering with a reflected light meter is probably about 12.7%. Cards of other reflectances, such as the widely-used 18% card, may be used to give the same results by making an appropriate numerical correction to the meter's exposure indication.

- Under normal circumstances, the value of the reflected meter calibration constant, *K*, of a digital camera's internal exposure metering system may be easily discerned with a simple test not requiring any photometric standards or instruments.

---

1. INTRODUCTION AND BENEDICTION

In discussions of the theory and practice of photographic exposure determination, considerable attention is given to the quantity "average scene reflectance". But it is not at all clear exactly to what that quantity applies, nor why in fact it is considered to have a certain value.

One of the most common explanations of it is: "Reflected light exposure metering systems are calibrated so as to assume an average reflectance of the scene being observed of x%." We also hear that "the reflective light metering system in a camera results in an object having a reflectance of x% being recorded with a mid-gray relative luminance value in the image."

There's a great deal of truth in each of these statements, but when we give the matter some intensive thought, we soon find that exactly what they mean is not really obvious.

In this article we will investigate at length this and related topics, largely through "between the lines" interpretation of the provisions of three ISO standards pertaining to photographic exposure metering.

Our safari through this jungle will not be a short or simple one for, as you will see, these matters do not lend themselves to nearly such simple explanations as we all often hope for. But fear not—the concepts are not complicated, and the math is mostly of the junior high school flavor. What is complicated is keeping track of what means what, and what numbers feed what, and which way up the ratios are—and penetrating the obtuse rhetoric and convoluted logic of the standards. But I've done all that for you (at great risk to my sanity)—all you need to do is follow along.

2. BACKGROUND

2.1 The word "exposure"

Discussions in this area are often complicated by the fact that the word "exposure" is legitimately used to describe two separate physical quantities. Their meanings are as follows:

> Exposure (1)—The combination of a certain effective relative aperture (f/number, for most purposes) and exposure time (shutter speed). This is the meaning of exposure that is quantified in logarithmic terms under the APEX system as *exposure value* (Ev).
>
> In this article, we'll use the coined symbol "Ex"[1] for this quantity.
>
> Exposure (2) —The product of the illuminance on some spot on the film or digital sensor and the time for which it persists (exposure time or shutter speed). It quantifies the physical phenomenon that (if we ignore certain wrinkles[2]) causes the image-receiving medium to respond to a certain predictable degree. This is the quantity that is identified by the symbol "E" in the famous "D log E" curve that characterizes the response of photographic negative film but is designated "*H*" in most scientific work.
>
> In this article, we'll use the scientific symbol, *H*, for this quantity.

A third, related property is *exposure result* (my term). This describes the effect of a certain *H* on the image. In the case of monochrome

---

[1] It's tempting to use "Ev", but that implies the logarithmic form of the quantity, and we will not always use the term in a context to which that is applicable.

[2] Such as *reciprocity failure*, which refers to the situation where, for quite long or quite short exposure times, the result for a certain illuminance-time product is not the same as for the same illuminance-time product with moderate exposure times.

negative film, this is the resulting *density*. In the case of a digital camera, this is the resulting digital code for the pixels involved.

2.2 Units

In this article, all equations and the values of all constants are predicated on luminance and illuminance being expressed in SI ("metric") units—*lux* and *candelas/m²*, respectively. In much writing in this field, the equations and constants are predicated on "customary" units—most often *foot-candle*s and *foot-lamberts*, respectively. Please keep this in mind when comparing such things as the values of constants mentioned here with those mentioned in other writings.

2.3 About lens transmission

In a lens with 100% transmission (no loss of light thorough reflection or absorption), the effective relative aperture of the lens (as an f/number) expresses the effect of the lens on exposure.

In various parts of the whole scheme of exposure determination, the effect of less-than-100% transmission, and of other phenomena such as natural and obstruction vignetting, are taken into account (usually by way of some numerical assumptions as to the degree to which those phenomena affect various relationships). These accommodations, while important, severely clutter up the tracking of various quantities through the equations that are involved. Accordingly, in this paper we will just assume that they are not a factor. The error in doing so is not important to our points here.

3. APPROPRIATE EXPOSURE

3.1 Exposure strategy

For the most part, the matter of determining an appropriate Ex for a particular photographic scene is an attempt to "plant" the range of *H*, resulting from the range of luminances encountered in the scene, appropriately within the range of *H* to which the film or digital imaging chain is "usably responsive". But what does "appropriately" mean?

Two strategies are widely embraced:

A. To have the *H* for the highest luminance object in the scene fall just below the top of the "usable range" of *H* for the film or digital sensor system involved. An advantage of this strategy is that it provides the best signal-to-noise ratio for the individual scene. This strategy is sometimes described as the "expose right" approach, where "right" alludes to the high end of the scale of exposure result (as in a histogram display of the exposure result in an image).

B. To have the *H* for each object in the field fall in the scale of *H* at a location proportional to the object's reflectance. This strategy is considered to provide the "most realistic" portrayal of objects in the printed or displayed image. Note that this approach places the *H* for a 100% reflectance object at nearly the top of the usable range of *H*.

For the most part, the discussions in this paper will be based on the adoption of strategy B or some adaptation of it.

3.2 Where is the top end, anyway?

With film, the determination of the "highest usable value of *H*" is tricky. The response curve of film has a long uniform portion bracketed by "gentle" starting and stopping portions. Thus, we must make some arbitrary decision as to where on the top end the "maximum usable *H*" lies.

It's also hard to determine where that is numerically from the ISO speed of the film since the definition of ISO speed for film more directly relates to the location of the bottom of the curve than the top.

In a digital camera, there is a clearly defined "top end" of the usable range of *H*: the value that produces an exposure result having the highest possible luminance coding under the color coding system ("color model") in use. In the 8-bit "RGB" family of image coding schemes, for a color neutral object, that is an RGB triple of 255,255,255.

Further, the ISO speed of a digital camera (when defined in a certain way) essentially defines (numerically) the maximum usable *H* for the camera. Since this figures into the whole matter of exposure metering, lets look at that in some detail before we move on.

3.3 ISO speed definition for digital cameras

ISO 12232, the standard for determining the ISO speed for a digital camera, provides for two different definitions of ISO speed:

1. The "signal-to-noise" definition: here, the ISO speed is defined as proportional to the reciprocal of the *H* that will give a signal-to-noise ratio (SNR) of 40 (16 dB[3]) in the "recorded relative luminance".

---

[3] Note that luminance has a dimensionality that is comparable to that of electrical power (not electrical voltage). Thus comparisons of luminance in dB may be made in the same way as for electrical power.

2. The "saturation" definition: here, the ISO speed is defined as proportional to the reciprocal of the maximum usable value of *H* (beyond which the sensor system would "saturate", causing clipping of further *H* values, "blooming", or other debilitating behavior).

It is this latter definition that fits into the discussions in this article, and we will assume its use.

4. FULFILLING THE EXPOSURE OBJECTIVE

4.1 The direct approach

To directly fulfill exposure objective A, we would need, for each "shot", to measure the luminance of the brightest object in the scene (using perhaps a "spot" exposure meter). We then take that quantity into account with the ISO speed of the film or sensor system (which reveals where the highest usable *H* is) to determine what Ex for the shot will satisfy the objective.

To directly fulfill exposure objective B, we would need, for each "shot", to measure the luminance of various important objects in the scene (again using perhaps a "spot" exposure meter). We then classify these objects into ranges of presumed reflectance. From this information, along with the ISO speed of the film or sensor system we determine what Ex for the shot will satisfy the objective. The famous "Zone System" for planning photographic exposure is essentially a discipline for guiding our work in this regard.

But neither of these scenarios constitutes a simple exposure metering system—they certainly aren't suitable for a "point and shoot" modality. So other exposure metering techniques are in widespread use.

4.2 Incident light metering

A desirable approach is to measure the illuminance of the light falling on the scene, using an *incident light meter*. From that value, one can draw inferences as to the luminance of objects of various reflectances. Then one can choose a value of Ex that will lead to values of *H* for those objects that fulfill our exposure objective, especially if that is objective B.

A practical disadvantage of this technique, of course, is that not every situation gives one the convenient opportunity to step into the scene in advance of the shot and take a measurement. And of course it doesn't fit in at all with "point and shoot" outlook.

In any case, we'll defer a technical analysis of incident light metering, and a further discussion of its advantages, until later (section 6), when we'll have in hand some needed background.

4.3 Basic reflected light metering

This is the technique used by the most common of the familiar hand-held exposure meters and by basic exposure metering systems embedded in cameras. It is the technique to which we will give the most attention in this article.

In this technique, the meter measures the average illuminance of the scene[4] and from that (along with a knowledge of the ISO speed of the film or digital sensor system) issues a recommended Ex to be used for photographing the scene.

The rule followed by the meter is very simple, and is given by this equation[5]:

$$\frac{t}{A^2} = \frac{K}{SL} \tag{1}$$

where t is the exposure time (shutter speed), A is the f/number of the aperture, S is the ISO speed of the film or digital sensor system, L is the measured average luminance of the scene, and K is the "reflected light meter calibration constant", whose value is adopted by the manufacturer during the design of the metering system. The quantity t/A^2 is the numerical value of the exposure (meaning 1)—the combination of shutter speed and aperture—"recommended" by the meter.[6]

If we are speaking of a typical classic hand-held exposure meter, its "calculator" is actually a circular slide rule that solves equation 1. It allows the photographer to choose different combinations of shutter speed and aperture, any one of which will give the value of t/A^2 dictated by the equation for the value of L measured by the meter proper, the value of S set into the calculator by the photographer, and

[4] For through-the-lens metering schemes, this is typically over just about the scope of the field of view; for the typical general-purpose hand-held meter, or the metering system of a camera with a non through-the-lens metering system, it is over some arbitrary field of view.

[5] This is prescribed by ISO 2720, the international standard for photographic exposure meters.

[6] This is the quantity whose APEX (logarithmic) form is *exposure value* (Ev).

the value of K "built into" the calculator by the manufacturer of the meter.

The working of the reflective metering system is dependent on "building into" the value of K an assumed value of the average scene reflectance. The reason is that from the average luminance of the scene (which is what the meter itself measures) and the average reflectance of the scene, the meter could determine the luminance upon the scene. This then leads to the luminance of a hypothetical 100% reflectance object, and from that the meter can determine the value of Ex that would give such an object the H considered the "maximum usable" value.

If we set aside a few wrinkles, and if we assume that the ISO speed (S) to be used by the metering system has been determined under the "saturation" basis as defined by ISO 12232, the value of K that should be adopted is given by:

$$K = 100R_0 \qquad (2)$$

where R_0 is the assumed average reflectance of the scene.

4.4 When this doesn't work right

Obviously, the reflective metering system will only produce the intended result if the actual average reflectance of the present scene is the same as the assumed average reflectance.

If the actual average reflectance is less than the assumed value, the metering system will recommend an Ex that may push the H produced by a 100% reflectance object above the "highest usable value", an undesirable "overexposure" situation in which "highlight detail" may be lost.

On the other side of the coin, if the scene has an actual average reflectance greater than the assumed value, the metering system will recommend an Ex that will not give a 100% reflectance item the highest usable H. That of course does no harm. Still, a corollary may be (only for scenes with a large range of reflectance) that lower reflectance items may be given H values less than the "lowest usable value", an undesirable "underexposure" situation in which "shadow detail" may be lost.

However, of those two situations, the latter is most often the most tolerable.

4.5 Building in some margin

In order to provide some margin against the possibility of overexposure, we can shift the value of K in a direction that produces lower values of H. This can be done by replacing equation 2 with this:

$$K = 100MR_0 \tag{3}$$

where M is a "margin factor". By making it less than 1, we shift K in a "safer" direction (with regard to the prospect of overexposure).

4.6 A parable

Suppose that we design a new exposure metering system based on an assumed average scene reflectance of 0.18 (18%), which we have heard is the average reflectance of a "statistically average scene" (whatever that means). If we take the view that "we don't need no stinking margin", we would set M to 1 (basically, "not have an M") and get a K of 18 to be used for the calibration of the meter.

But suppose that we find in field trials that, in "too many" cases, an unacceptable overexposure results.

The practical solution, of course, is for us to reduce the value of K in the meter design. Perhaps we would do so by "1/2 stop", to about 12.7. This will reduce the number of cases in which "unacceptable" overexposure occurs.

Now, how do we describe the basis for this change in K?

There are two possibilities:

1. "I guess I should have left some margin after all. I'll introduce a margin factor M of 0.707 to give a 1/2 stop margin. I'll keep the assumed average reflectance at 18%—I still believe that this is a good value for a 'typical' scene."

2. "I guess an assumed average scene reflectance of 18% was overoptimistic. Evidently too often the actual average reflectance is lower than that. So that our meter 'fails safe', I'll change the assumed average reflectance to 12.7%." (And not introduce the factor M.)

Either outlook, of course, would result in a new value of K of 12.7.

To let us deal clearly with this example later, let's identify the value of assumed average reflectance (under explanation 1) as R_0, and our "adjusted" value of R_0 (under explanation 2) as R_1. Then:

$$R_1 = MR_o \tag{4}$$

where *M* is the value of the margin factor under explanation 1 (0.707).

Why might the designer choose to explain what was done in terms of explanation 1 rather than explanation 2? Well, for one thing, it's the best way to recognize that the starting point in this whole exercise was the belief that a good value of average reflectance for a "typical" scene is in fact 18%.

We can now begin to see why, in connection with average scene reflectance in connection with exposure metering, a value of 18% is often stated by some writers, and a figure of "12%-13%" by others. As we just saw, this does not represent different opinions as to the average reflectance of the "typical" scene, nor does it relate to different calibrations of the meter.

5. AVERAGE REFLECTANCE AND THE STANDARDS

It is interesting to see if those particular numerical values are prescribed by, or implied by, the various ISO standards relating to exposure metering. It isn't easy—the language of the standards is often obtuse and seems to be based on a desire to prevent any "civilians" from knowing exactly what the standards authors really had in mind.

5.1 Average reflectance implications of the ISO speed standard

ISO 12232 (giving the definition of ISO speed) states in a footnote that the choice of the constant in its "saturation" definition of ISO speed is in effect based on achieving this relationship: an 18% reflectance object in a "statistically average" scene would produce an *H* which was 1/2 stop below the maximum usable *H*. (Presumably this means in a shot taken with the Ex that would be indicated by a meter regarding the scene and which has been set to the ISO speed that had been determined under the saturation definition—the authors don't bother to say that.)

This can be interpreted as meaning that, with ISO speed defined as given in the standard, the meter calibration would be based on an assumed 18% average scene reflectance and a 1/2 stop margin (M=0.707).

But that relationship would only hold for a specific value of *K* for the meter (12.7 as a matter of fact), and this standard does not prescribe a value of K (such would not be a proper role of this standard), nor even assume one specified elsewhere. Or does it?

Elsewhere in this standard, there is a reference to another standard, ISO 2721, which covers automatic exposure control for cameras (essentially, a standard for the calibration of "embedded" exposure meters). There is a vague hint that the meter calibration prescribed by that standard was somehow involved in the choice of the definition of saturation ISO speed in ISO 12232.

When we look at ISO 2721, we don't find the prescribed meter calibration expressed in the same terms as it is in ISO 2720 (for "non-embedded" exposure meters)—that is, there is no equation with K in it (and K is not even mentioned). Neither is these any mention of assumed average scene reflectance nor of overexposure margin.

Rather, the prescribed automatic exposure meter calibration is described as that which would produce, for an object having a luminance which is the average for the scene, an H of 10 lux-sec.

Working this back through the basic photometric equation that relates H to object luminance and the value of Ex used for the exposure, plus the ISO 2720 equation defining meter calibration in terms of K, reveals that ISO 2721 actually prescribes a K of 12.7 for embedded exposure meters!

So the authors of ISO 12232 were indeed thinking about K of 12.7, which they chose to think of as resulting from an assumed average scene reflectance of 18% and a margin of 1/2 stop ($M=0.707$).

This value of K is within the range of K (10.6-13.4) allowed for by ISO 2720, the standard for the calibration of (non-embedded) exposure meters.

It is also very near the value of K, 12.5, which it has been said is utilized by Canon in the exposure metering systems in their cameras. We'll check that out for a real Canon camera in section 5.5.

5.2 Another interesting relationship

The definition of saturation-based ISO speed from ISO 12232 and the reflected light metering equation from ISO 2720, taken together, lead to this situation:

> For an exposure using the Ex recommended by the meter (with the saturation-based ISO speed set into the meter), for any object whose luminance is the same as the average luminance of the scene, the value of H in the image will be:

$$H = \frac{K}{100} H_{mu} \qquad (5)$$

where H_{mu} is the maximum usable H used as a basis for determination of the ISO speed of the camera.

Of course, since, for a uniformly-illuminated scene, the luminances of the various objects are proportional to their reflectances, then this same result will occur for any object whose reflectance is the same as the actual average reflectance for the scene.

And since, for a scene of uniform reflectance (such as a frame-wide "test card"), the reflectance of any part of the scene is the same as the average reflectance, then the H for any point on the scene will be K/100 times the maximum usable H.

5.3 Can we test a camera to find the value of K?

Equation 5 tells us that, if we take a metered shot of a full-frame test target of any uniform reflectance and inspect the image, and find that the exposure result represents "x%" of the maximum possible recorded luminance[7], this tells us that the value of K used in the meter calibration is "x".

5.4 Does this reveal to us the value of assumed average scene luminance used in the meter design?

No. As shown in equation 3, the value of K is 100 times the quantity MR_0 (that is, R_1). If we know K, but do not know the margin factor, M, adopted by the designer, we cannot determine the assumed scene luminance, R_0.

The value of K does, however, reveal the "assumed average scene luminance with a margin allowance built in", R_1.

Other than out of intellectual curiosity, why might we want to know the value of R_0 itself? As we'll see a little later, one reason would seem to be in connection with "gray card incident light metering". But, as we'll see then, it may turn out that the quantity we really want to know is R_1, which is in fact K/100. And we can find K by the simple test described in section 5.3.

[7] Note that to do so we must take into account that RGB coding is nonlinear with relative luminance, the exact relationship depending on the specific RGB coding system in use.

5.5 A practical confirmation

In a test run on my Canon EOS 300D digital SLR camera, based on the principle described earlier, the result was that the exposure result for areas on the uniform test target[8] represented an H of 12.7% that of the maximum usable *H*. Of course, as discussed in section 5.3, that suggests a value of *K* of 12.7. How about that! (Recall that it has been widely stated that Canon utilizes a value of K of 12.5.)

6. INCIDENT LIGHT METERING

We now return to the matter of incident light metering.

6.1 Why incident light metering?

We saw earlier that the dependence of the reflected light metering approach on an assumed value of average scene reflectance leads to great opportunity for inconsistent exposure metering performance, owing to the unpredictability of actual average scene reflectance.

We can overcome this intrusion of the unpredictable average reflectance of the scene by utilizing *incident light metering*, using an exposure meter specifically designed for that technique.

In this technique, the exposure meter does not measure the average luminance of the scene but rather the illuminance of the light falling on the scene. From that (along with a knowledge of the ISO sensitivity of the film or sensor system), the meter issues a recommended Ex to be used for photographing the scene.

The rule followed by the meter is again very simple, and is given by this equation[9]:

$$\frac{t}{A^2} = \frac{C}{SE} \qquad (6)$$

where *t* is the exposure time (shutter speed), *A* is the f/number of the aperture, *S* is the film sensitivity ("speed") as an ISO rating, *E* is the measured illuminance of the incident light, and *C* is the "incident light meter calibration constant", whose value is adopted by the meter manufacturer during the design of the metering system.

---

[8] That result was RGB = 100,100,100. Under the sRGB color model used for the test image, this represents a luminance of 12.7% of the luminance represented by the maximum possible RGB triple, 255,255,255.

[9] Again from ISO 2720

Here, average scene reflectance is no longer in the picture. The *H* for an object of any given reflectance will end up in the scale of *H* just where the manufacturer decided was desirable. Thus this technique has the promise of yielding more consistent exposure indications than reflective light metering. Accordingly, it is widely used for much demanding studio photography, as well as in professional cinematography.

To have the incident light meter give the same Ex recommendation as a certain reflected light meter would have given in the ideal situation (that is, where the actual average reflectance of the scene was in fact the value assumed in the meter design), we need to set C as follows:

$$C = \frac{\pi K}{R_0} \qquad (7)$$

where *K* is the value it has in the reflected light meter and R_0 is the assumed average scene reflectance that played a part in the choice of *K*. (The π is only present because of the SI units used herein for the various photometric quantities and thus for *K* and *C*.)

In order to set C to this value, we need to know R_0, but all we can get from "reverse-engineering" of the reflected light meter, or even by being told its value of *K*, is R_1 (that is, MR_0).

But in fact the basis described above for choosing the value of *C* might not be the best strategy. Because of the need to avoid overexposure, the manufacturer of the reflected light meter will likely have (by introducing the factor *M*) chosen a value of *K* such that, in the "ideal" case where the average scene reflectance is precisely that assumed in the meter deign (R_0), the exposure given by the reflected light meter might be less than desirable.

With incident light metering, we are freed from the adverse affect of variation in actual average scene reflectance. Accordingly, perhaps we no longer need the "margin" introduced by the factor *M*.

Since $R_1 = MR_0$, we can rewrite equation 7 this way:

$$C = \frac{\pi KM}{R_1} \qquad (8)$$

Then, if we shed the factor *M* (mathematically, change it to 1, "no margin"), then the equation for the appropriate value of *C* becomes:

$$C = \frac{\pi K}{R_1} \qquad (9)$$

In our example, R_1 is 12.7%. It is of course the apparent average reflectance that seems to have been used to determine the value of K if we think of margin having being built in by choice of average reflectance, not by the introduction of a value of M less than 1.

We noted earlier that, assuming the ISO speed is determined in accordance with the saturation definition of ISO 12232, then the value of K that fulfills the premise of the ISO speed definition is:

$$K = 100MR_1 \quad (3)$$

If we substitute this into equation 7, we get:

$$C = 100\pi$$

or approximately

$$C = 314 \quad (10)$$

This value of C is in range of the value of C allowed by ISO 2270.

From this we can draw the conclusion that the framers of ISO 2270 had in mind either that:

1. An incident light meter is expected to provide a result 1/2 stop "hotter"[10] than a reflective light meter whose value of K is predicated on an assumed scene reflectance of 18% and a margin of 1/2 stop and which is operating on an ideal situation (that is, a scene whose actual average reflectance is 18%), or

2. An incident light meter is expected to provide a result identical to that of a reflective light meter whose value of K is predicated on an assumed scene reflectance of 12.7% and no margin[11] and which is operating on an ideal situation (that is, a scene whose actual average reflectance is 12.7%).

Note how this outlook again nicely accommodates both those who feel that this standard implies an average scene reflectance of 18% and those who feel that it implies an average reflectance of 12.7%!

---

[10] Thus shedding the margin allowance used by the reflective light meter, on the premise that with the greater accuracy of incident light metering none is needed.

[11] That's the same reflective light meter as in possibility 1, just described differently! In this case, there is no margin allowance to shed.

6.2 The gray card

If we don't have an actual incident light meter, can we still practice this desirable metering technique? We can indeed. We use the normal camera metering system to make a measurement, not on the scene about to be photographed, but rather on a target of a known, uniform reflectance (a "gray card") that is illuminated by the light that falls on the scene. We capture the Ex indicated by the metering system and use it for the actual shot of the scene.

What reflectance should the card have? If in fact we want the exposure result of this process to be the same that the camera's reflective light metering system would have given in an ideal case (that is, where the scene average reflectance is the one contemplated in the design of the metering system), then the card should have reflectance R_0 (18% in the example above).

But, just as in the story about adopting "real" incident light metering, if we feel that the best exposure result would be to "dispose of the margin", then the proper reflectance for the gray card would be MR_0 (12.7% in the example above).

6.3 What about the 18% gray card?

We have just established that the use of a gray card with a reflectance of about 12.7% is perhaps most appropriate for performing incident light metering with the camera's reflected light metering system. But in fact, we most often read about this being done with a card having a reflectance of 18%. What's with that?

It is likely that at one time, the objective underlying the recommended calibration of an incident metering system was in fact to produce the same Ex recommendation as would be given by a reflected light meter operating in an ideal situation—that is, on a scene whose actual average reflectance was the same as the average reflectance assumed by the calibration of the metering system.

(Note that above we suggested that the modern approach is to have an incident metering system give an Ex about 1/2 stop greater than that—the result of realizing that the "margin" typically built into the reflected light metering system is not needed in an incident light metering situation.)

We see evidence of this in the fact that, in the metering calibration standard of that earlier era, the value of *C* (the calibration constant for incident light meters) was about 70% of today's value.

If in fact we make the comparison between the values of *K* and *C* suggested by the standard of that time, we will find that this implies an assumed average scene reflectance of about 18%.

The 18% reflectance gray card likely emerged under that situation.

6.4 Another glimpse of the past

I own a Miranda Cadius[12] hand-held exposure meter, over 45 years old.[13] It can operate in both reflected light and incident light modes. It has on its back tables relating the meter reading to actual values of luminance (for the reflected light mode) or illuminance (for the incident light mode).

From those tables, and the relationship built into the meter's calculator, one can unequivocally determine the values of K and C built into the meter design. (What a joy!)

Comparing those values (in the fashion described earlier) clearly suggests that the manufacturer had based the value of K on an assumed average scene reflectance of 18%.

6.5 So can we use an 18% card anyway?

Now, knowing that a target card with a reflectance of 12.7% is perhaps most appropriate for gray card incident light metering, can we still use our 18% reflectance gray cards? Absolutely—we make an exposure measurement on the 18% gray card with a reflected light meter and then use 1/2 stop greater exposure for the shot.

In fact the Kodak 18% gray cards today have a little sticker on them directing the user to do just that!

So why don't we find 12.7% gray cards sold? Beats me.

7. MATRIX AND EVALUATIVE METERING SYSTEMS

The discussions above have been predicated on a reflected light exposure metering technique based on a single measurement, of average scene luminance. We have emphasized that the dependence

---

[12] Sometimes, but inaccurately, spoken of as the "Cadius I" model, by way of contrast with the later "Cadius II" model.

[13] It was bought in a shop in New York City that (with hundreds of others) was torn down to make room to build the World Trade Center!

of this technique on an assumed value of average scene reflectance made it actually rather unreliable.

To improve on this situation, most sophisticated cameras today use some type of intelligent multiple-point measurement technique, such as the “Matrix” metering system employed by Nikon and the “Evaluative” metering system employed by Canon.

These systems use complex algorithms to attempt to discern, from the measure luminance of the scene at a number of points in the frame, what the distribution of luminance in the scene is, and from that what value of Ex is likely to give the best overall exposure results. This approach cannot really be discussed in the terms in this paper.

Other variations of the basic “average luminance” metering are also used in some cases, such as metering modes that have a restricted field of view (making a measurement of average luminance only over an arbitrary part of the frame), or patterns that average over a large portion of the frame but “weight” the measurements so that the contribution of luminance measurements from near the center of the frame to the average is greater than for the measurements from other parts of the frame.

Such systems will of course for many scenes give different indications of Ex than would the basic reflected light metering systems we have discussed above—if they didn’t, there would be no reason to have them. And, especially for the intelligent multiple point system, we cannot accurately describe their performance in the simple terms of this article.

Nevertheless, it commonly turns out that these “restricted” or “weighted” metering patterns, and even intelligent multiple-point metering systems, are “calibrated” such that, for the specific case of a shot of a frame-wide uniform luminance test card, the Ex chosen by the metering system is in fact generally consistent with the results discussed in this paper.

8. ABOUT “MID-SCALE GRAY”

It is often said that the objective of the usual calibration of a reflected light exposure meter is that an object whose reflectance is the average reflectance of the scene will be given an exposure result that is considered “mid-scale gray”, and that an exposure result that represents a luminance of about 18% of the luminance represented by the largest possible exposure result (that would be about RGB 118,118,118 in an sRGB color space) would be considered such a mid-scale gray.

I won't attempt to comment on the idea that 18% relative luminance should be thought of as mid-scale gray.

Note, however, that as we see above, for a camera automatic exposure system calibrated in accordance with ISO 2721, or for a shot taken under the guidance of an exposure meter calibrated under ISO 2720 with a *K* of 12.7, an object whose reflectance is the same as the average reflectance of the scene will be given an 12.7% relative luminance result, not an 18% result.

#