APEX—The Additive System of Photographic Exposure

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ABSTRACT

The Additive System of Photographic Exposure (APEX) provides for stating several factors involved in photographic exposure in logarithmic form. In this way, calculation of the "proper exposure" for a given situation may be done manually using only addition. Although the importance of that has largely faded since the time the system was developed, the scheme is still widely used in technical work relating to photographic exposure, especially the quantity "exposure value" (E_V). This article explains the APEX system, and gives cautions about irregularities in its usage that are often encountered.

1 INTRODUCTION

1.1 APEX— The Additive System of Photographic Exposure

The Additive System of Photographic Exposure (APEX) provides for stating several factors involved in photographic exposure in logarithmic form. In this way, calculation of the "proper exposure" for a given situation may be done manually using only simple addition.

This convenience was a principal motivation for the development of the system (first completely promulgated in 1961), which took place when the use of photographic light meters was not universal and cameras with internal exposure metering systems were almost nonexistent.

Although changes in practice and technology have diminished the importance of this objective, it is today still common and convenient to express certain exposure-related factors in APEX terms.

The factors represented in this system are:

- Exposure time (shutter speed)
- Aperture (in the f/number sense)
- Photographic exposure (the joint effect of the two above factors)
- ISO speed (film or digital imager "sensitivity")
- Metered scene luminance (brightness)
- Metered incident light illuminance (illumination)

1.2 Base 2 logarithms

The APEX definitions of exposure factors utilize “base 2” logarithms. As a result, a change of one unit in an APEX value corresponds to a 2:1 change in the actual factor, a change that photographers call “one stop”.[1] Thus, experienced photographers can readily appreciate the significance of changes in factors expressed in APEX terms.

The base 2 logarithm of a number can be calculated by taking the common (base 10) logarithm (“log”) of the number and dividing that by the common logarithm of 2 (which is approximately 0.3010).

1.3 “Correct exposure”

There is of course no unique way to calculate the appropriate exposure for a particular photograph, especially if we consider the diverse artistic and technical objectives that may be involved and the range of properties that the scene might exhibit.

By “correct exposure” in this article we mean the exposure that would be arbitrarily dictated by a widely-accepted mathematical relationship, the exposure we would expect to have “recommended” by a properly-performing photographic exposure meter.

1.4 Terminology and notation

The various exposure factors in their APEX forms are all spoken of as “values”, as for example “aperture value”. The word “value” is thus an arbitrary cue that the APEX (logarithmic) form of the factor is meant.

In this article, I will often have to use the word “value” with its common meaning. To avoid any confusion, here when I mention APEX *values* I will italicize “value”.

Formally, the symbols for the APEX values all have a “v” subscript, as A_v (subscript lower-case “V”). In documents where subscripts cannot be rendered, the symbols are presented this way: Av (lower-case “V”). And in fact, I will use this convention here, since it is what is most often seen.

We will be speaking of two distinct factors having the unfortunately-similar formal names *luminance* and *illuminance*. To avoid confusion between these terms, we will often state, parenthetically, the less precise but more recognizable terms *brightness* and *illumination*, respectively. (“Brightness” is the term used in APEX anyway.)

[1] The term most directly relates to *aperture*. It goes back to the time when cameras were first equipped for control of aperture. Commonly, a metal plate carrying a number of holes of different diameter passed through a transverse slot in the lens barrel. It was said to “stop down” the lens aperture, and the different holes were said to be “stops”. The photographer moved the plate to put into place the appropriate stop for a particular exposure. Commonly, successive holes had areas that differed by 2:1. Thus a 2:1 change in aperture area came to be known as a “one stop” change.

It is customary for the tables showing the APEX forms of the various factors to cover the range of integer values from 0 through 10 or so. Values outside that range may of course occur. Negative and fractional values are also perfectly meaningful.

The norms for the International System of Units (SI) dictate that for compound units we can use either the names of the units (*e.g.*, "candelas/square meter") or the abbreviations ("cd/m^2") but not both ("$candelas/m^2$").

But (mea culpa) in some cases, in the interest of the best compromise between clarity and compactness, I will use the forbidden construct.

2 ORIGIN AND STATUS

American Standard ASA PH2.5-1960, American Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous-Tone) prescribed two ways of stating the sensitivity of the film, one "direct" (often called at the time the "ASA speed" (written, for example, "ASA 100"), and the other "logarithmic" (written, for example, for the same speed, "ASA 5°"). The latter form was essentially equivalent to what became the APEX speed value, S_V.

The narrative that introduced the latter form went on to observe that it would probably be desirable to establish optional logarithmic representations of all the factors involved in exposure metering, thus opening the door to the development of the APEX system. An example set of defining equations was given.

The APEX system of notation itself was first promulgated by American Standard ASA PH2.12-1961, *American Standard General-Purpose Photographic Exposure Meters (Photoelectric Type)*. But is was essentially dead on arrival, being rendered irrelevant by the then-current tools and techniques of exposure metering.

That standard was superseded by American National Standard ANSI PH3.49-1971, *American National Standard for general-purpose photographic exposure meters (photoelectric type)*. In this new standard, it is mentioned that the APEX system has not been used on consumer products and accordingly it is not included in the standard proper; however, because it has been found useful in engineering, it is included in an appendix for historical reference.

That standard was superseded by ISO Standard ISO 2720-1974, *Photography—General purpose photographic exposure meters (photoelectric type)—Guide to product specification*. The APEX system of notation is not covered by (or even mentioned by) this standard, nor is it covered by any other contemporary standard.

But the APEX system was given new life in the matter of the encoding of various photographic metadata items (aperture, shutter speed, etc.) in the metadata section of the "Exif"[2] standard for digital photographic images. It was decided that in the interest

[2] It is widespread but erroneous to refer to "the Exif" or "the Exif data" to mean the metadata portion of an Exif file, but of course "Exif" refers to an overall image file format (the Exchangeable Image File format).

of most compact encoding, a logarithmic basis for encoding the various values was desirable, and, given that the APEX system existed, the Exif metadata scheme was based on APEX. This new life of APEX is covered by many standards, which I will not attempt to catalog here.

3 THE CALIBRATION CONSTANTS

3.1 Introduction

International Standard ISO 2720 prescribes a way of defining the "calibration" of a photographic exposure meter. By "calibration" is meant, for a given scene luminance (or, for incident light metering, illuminance) and a given stated film sensitivity, just what *photographic exposure* (combination of exposure time and aperture) will the meter recommend.

For reflected light metering, the calibration is defined by the *reflected light exposure metering calibration constant*, K.

For incident light metering, the calibration is defined by the value of the *incident light metering calibration constant*, C.

Note that the numerical values of these constants is affected by the unit used for luminance or illuminance involved in the relevant context. It is the usual practice today to state them as applies to the use of SI units for the luminance or illuminance.

Note that for both types of metering, a greater value of K or C means that, other factors being the same, the meter will give a greater exposure recommendation.

3.2 The exposure metering equations

3.2.1 *Reflected light metering*

The standard equation for determining the "recommended photographic exposure" with reflected light metering (that is, based on measurement of the average luminance of the scene), is:

$$\frac{t}{N^2} = \frac{K}{L_s S} \tag{1}$$

where t is the exposure time in seconds; N is the aperture, as an f/number (these together comprising the "recommended photographic exposure"); L_s is the metered average scene luminance (brightness), in some appropriate unit; S is the sensitivity (speed) of the film or digital imager, as an ISO speed number; and K is the *reflected light exposure metering calibration constant*.

Under the applicable standard, the value of K for an exposure meter may vary over a modest range. There is no inherently "proper" value, since the matter of "proper exposure result" is a subjective one at best. The manufacturer of a certain exposure meter model is free to choose a value of K (from within that range) to provide an exposure result the manufacturer hopes will be considered "appropriate" by most users in most situations.".

When we use APEX values, this equation becomes:

$$Av + Tv = Bv + Sv \qquad (2)$$

We see how the use of the APEX "logarithmic" values simplifies the work of making a calculation of exposure factors.

But note that no APEX form of the calibration constant, K, is visible. We would expect it to appear, in logarithmic form (an APEX "value", perhaps Kv) as a term in the equation:

$$Av + Tv = Bv + Sv \ + \ Kv \qquad (3)$$

But we do not see that term in the actual equation. That is because a certain value of *K* has been "built in" to the definition of the scale for Bv. The result is that the term reflecting the calibration constant becomes zero and thus disappears. The object of this ploy is to make the APEX exposure equation as simple as possible.

What is the value of K that is built into the definition of Bv? As in the case of the matter of K for an actual exposure meter, none is specified.

The fact is that any "worker" with the APEX system must think of it as a replacement for the calculator on a traditional exposure meter, which is visualized as having a certain value of K (perhaps the one the worker would have adopted were he to be designing an exposure meter), and then consider the definition of Bv in the light of that value of K..

3.2.2 *Incident light metering*

The standard equation for determining the "recommended photographic exposure" with "incident light metering" (that is, based on measurement of the illuminance on the scene), is:

$$\frac{t}{N^2} = \frac{C}{E_S S} \qquad (4)$$

where t is the exposure time in seconds; N is the aperture, as an f/number (these together comprising the "recommended photographic exposure); L_s is the metered illuminance on the scene, in some appropriate unit; S is the sensitivity (speed) of the film or digital imager, as an ISO speed number; and C is the *incident light metering calibration constant*.

As for the constant C, the applicable standard allows it to vary over a modest range, under the same rationale as for K.

When we use APEX values, this equation becomes:

$$Av + Tv = Iv + Sv \qquad (5)$$

For illuminance, whose normal scientific symbol is E, the APEX value has the symbol "Iv") ("I" for "illuminance").

But note that here no APEX form of the calibration constant, C, is visible. A certain value of C has been "built in" to the definition of the scale for Iv. Again, the object is to make the APEX exposure equation as simple as possible.

And so on and so forth, as with the case for Bv and K.

3.3 Discussion

It may seem odd (it is odd!) that the actual values indicated by the APEX *values* Bv and Iv should depend on the choice of parameters whose original use was to define the calibration of a photographic exposure meter. But keep in mind that the original objective of the APEX system was to facilitate the calculation that, on a complete photographic exposure meter, is done by the "calculator".

So, was the photographer using this new tool likely to have, for example, measured the illuminance upon the scene with a technical illuminometer (rather than a photographic exposure meter)? Probably not. More likely, an empirical assumption would be made, such as "late afternoon sun, therefore . . .". And so would the photographer have decided what value of C he "subscribed to"? Not likely.

But suppose he did. Would he then, having decided what the illuminance on the scene probably was, calculate Bv, and then calculate what exposure he would use? That would of course run contrary to the entire purpose of APEX, to facilitate exposure calculation.

More likely, he would work from a page in an article in a photo magazine that told, for various lighting situations (like "late afternoon sun"), what value of Bv should be assumed.

Now did the author of that page choose a value of C to underlie his work, based on his favorite value of C, the one that best fulfills his "exposure philosophy? Not likely. It would really be silly to fret over the precisely the best value of C for a process that is based on gross assumptions about scene luminance.

So this story does not reach from cover to cover. But because APEX never did come into widespread use by working photographers, these conundrums remained un resolved.

As we will see shortly, the tables typically used to relate "regular" values of the various exposure factors to their representation by APEX values are predicated on values of C and K that are chosen for a far more "pragmatic" reason: to make the tables have "handy" values of the exposure factors for integral APEX values.

4 THE DEFINING EQUATIONS

See Appendix A for the underlying equations defining all APEX values.

5 TABULAR VALUES

5.1 Introduction

The following tables present relationships between the APEX *values* and the underlying values of the various factors for which APEX notation is provided. For Bv and Iv, there are no singular relationships; as was discussed above, the relationship is predicated on the essentially-arbitrary values of the calibration constants K and C that have been adopted.

So for those two quantities, the tables presented here are those often published. In them, values of K and C are used that make the values of the underlying quantities, for integral values of the APEX *values*, tidy[3].

5.2 The units

For Bv and Iv, the underlying quantities are presented in two units, the first being the "non-SI" unit and the second being the SI unit[4].

5.3 The numbers

In all the tables, integer values of the APEX value from 0 through 10 are shown. Of course, values outside that range (where practical) are valid, as are fractional values.

The values of the underlying quantity stated for each APEX value step are the exact ones (typically to 3 significant figures) given by the definition (in the case of Bv and Iv, for the value of K or C on which the table is predicated). Where another number is shown in square brackets, it is the value rounded to the nearest one of the standard series of values for that quantity prescribed for use in photography.

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[3] It is the "non-SI" unit values that are "tidy", a result of the fact that when the APEX system was being introduced, the non-SI units for these qualities were the most widely used in US practice.

[4] SI refers to the International System of Units, the modern "metric system". These units are preferred for technical and scientific work, but in practical photography, the "non-SI" units are still often used.

5.4 Aperture value (Av)

Aperture value (Av) represents the aperture in its "relative aperture" (f/number), form (*e.g.*, f/3.5). A larger Av represents a smaller aperture (larger f-number) and thus less exposure.

Aperture value (Av)	**Aperture**
0	f/1.00 [1.0]
1	f/1.41 [1.4]
2	f/2.00 [2.0]
3	f/2.83 [2.8]
4	f/4.00 [4.0]
5	f/5.66 [5.6]
6	f/8.00 [8.0]
7	f/11.3 [11]
8	f/16.0 [16]
9	f/22.6 [22]
10	f/32.0 [32]

Note that when speaking of the aperture in terms of the f-number as such in scientific work, a common symbol for the f-number is *N* (but this is far from universal). When working in the field of APEX, the symbol "*A*" is used (thus the APEX value symbol, Av).

5.5 Time value (Tv)

Time value (Tv) represents the exposure time (shutter speed) in seconds. A larger Tv represents a “faster” shutter speed and thus a lower exposure (it works in the same direction as the denominator of shutter speed).

Time value (Tv)	Exposure time (sec)
0	1
1	1/2
2	1/4
3	1/8
4	1/16 [1/15]
5	1/32 [1/30]
6	1/64 [1/60]
7	1/128 (1/125]
8	1/256 (1/250)
9	1/512 [1/500]
10	1/1024 [1/1000]

5.6 Speed value (Sv)

Speed value (Sv) reflects the sensitivity of the film or equivalent, expressed as an “ISO speed”. A larger Sv represents a greater sensitivity.

Speed value (Sv)	Sensitivity (ISO speed)
0	3.125 [3]
1	6.25 [6]
2	12.5 [12]
3	25
4	50
5	100
6	200
7	400
8	800
9	1600
10	3200

This table is based on the relationships, in standard ASA PH2.5-1960, between the normal and logarithmic forms of the film speed rating (the latter being the progenitor of the APEX *value*, Sv) for the “standard” film speeds defined by the standard.

The formula in that standard, however, gives slightly different values of the speed for the integer APEX *values* (the difference being only about 0.093 stop).

5.7 Brightness value (Bv)

Brightness value (Bv) indicates the metered luminance (brightness) of the scene. A larger Bv represents greater scene luminance. The table shows the values of Bv on the basis of two different luminance units. This table is predicated on the value of K being 3.333 for luminance in footlamberts, 11.45 for luminance in candelas/m^2.[5]

Brightness value (Bv)	Scene luminance (brightness)	
	footlamberts	candelas/m^2
0	1	3.4
1	2	6.9
2	4	14
3	8	27
4	16	55
5	32	109
6	64	219
7	128	439
8	256	877
9	512	1754
10	1024	3508

The values shown for the unit footlambert are the precise theoretical ones (and the value of K in the defining equation was chosen to make them "tidy"). The values shown for the SI unit, candelas/m^2, are derived using the standard conversion between the two units to an appropriate precision.

[5] A K of 12.5 is common today in actual exposure meters.

5.8 Incident light value (Iv)

Incident light value (Iv) indicates the (metered) illuminance (illumination) on the scene. A larger incident light value represents a greater illuminance. The table shows the values of Iv on the basis of two different units for illuminance. This table is predicated on the value of C being 20.83 for illuminance in footcandles, 224.2 for illuminance in lux.[6]

Incident light value (Iv)	Illuminance (illumination)	
	footcandles	lux
0	6.25 [6]	67
1	12.5 [12]	135
2	25	269
3	50	538
4	100	1076
5	200	2152
6	400	4304
7	800	8608
8	1600	17260
9	3200	34432
10	6400	68864

The values shown for the unit foot-candle are the precise theoretical ones (and the value of C in the defining equation was chosen to make them “tidy”). The values shown for the SI unit, lux, are derived using the standard conversion between the two units to a precision of one unit.

[6] A C of 250 is common today in actual exposure meters using a flat (“cosine”) receptor, 340 for meters using a dome (“cardioid”) receptor.

6 EXPOSURE VALUE (E_V)

The typical "reflected light" photographic exposure meter (the most commonly-used form by "hobby" photographers) measures (average) scene luminance (which we could state as B_V, an APEX *value*). This finding goes into some type of exposure calculator, typically a circular "slide rule", into which the photographer has set the sensitivity of the film or digital imager (as an ISO speed).

The calculator then presents a continuum of aperture versus shutter speed, any matching pair of which produce the exposure the meter "recommends" for the combination of scene brightness and film sensitivity.[7] The photographer makes a choice of a pair in order to suit the particular photographic task. The state of this calculator constitutes a value of Av+Tv, a number that we may say defines the recommended "photographic exposure".[8]

To facilitate discussions of this, APEX defines a composite value, Exposure Value (Ev), as:

$$\mathrm{Ev} = \mathrm{Av} + \mathrm{Tv} \qquad (6)$$

A larger value of Ev represents less exposure.

We can then rewrite the fundamental reflected-light metering exposure equation as:

$$\mathrm{Ev} = \mathrm{Bv} + \mathrm{Sv} \qquad (7)$$

Many light meters will in fact report their recommended exposure in terms of Ev as well as in aperture-shutter speed pairs.

6.1 Implications on assumed scene reflectance

If we compare the equations for reflected and incident light metering, using the embedded values for K and C, we might conclude that they jointly imply that the reflective light meter operates on the basis of an assumed average scene reflectance of about 16%. But this matter is not that simple (owing to such matters as the inclusion of "overexposure headroom" in the reflected light metering strategy but not the incident light strategy).

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[7] This approach is based on an assumption of (a) average scene reflectance, (b) the range of reflectance from the darkest to the lightest object in the scene, and (c) a certain "strategy" for the resulting photometric exposure distribution.

[8] Called that to distinguish it from the quantity (best called "photometric exposure) that describes the total amount of "light energy" per unit area of the film (illuminance times time) as the result of the exposure.

In any case, interpreting this relationship, and relating it to the “12.8%” and “18%” average scene reflectance values often mentioned in the theory of exposure metering standards, is a complex issue beyond the scope of this article.

7 ODDS AND ENDS

7.1 Sunny 16

Experienced photographers often use a “rule of thumb”, sometimes referred to as the “sunny 16” rule, to estimate outdoor exposure when no meter is available. This rule suggests, for exposure on a scene illuminated by full sunlight[9], an aperture of f/16 and a shutter speed of one over the ISO speed number of the film (such as f/16 and 1/200 sec for ISO 200 film).

If we work backwards through the APEX incident light exposure equation, we find that this rule is essentially predicated on a scene illumination of about Iv 9.6, about 5000 footcandles (or about 50,000 lux).

8 EXPOSURE COMPENSATION – THE “Ev” SETTING

This topic is not really part of APEX, but it’s a matter that is usually described in terms of an APEX *value*, so we will lightly treat it here.

Many cameras have provision for forcing the camera to use an exposure that is greater or less, by a user-determined amount, than the exposure the metering system would normally choose. This is often useful for cases in which certain properties of the scene would frustrate the metering system’s ability to secure the effect desired by the photographer.

An example is a scene where a large percentage of the image area has a very low brightness, or a scene where a large percentage of the image area has a very high brightness. The camera’s metering system, left to its own devices, would call for an exposure that will cause these majority areas to be recorded as a nice middle gray for either scene.

The amount of this “exposure compensation” is often adjustable in steps of 1/2 or 1/3 “stop”, often up to a maximum of 2 or 3 stops in either direction.

In effect, the use of this feature makes the basic exposure equation followed by the camera become:

$$\mathrm{Av} + \mathrm{Tv} = \mathrm{Bv} + \mathrm{Sv} - \mathrm{Xv} \qquad (8)$$

where Xv is the exposure compensation setting in APEX-like units. (Note that Xv is not a term defined in APEX—it is my own notation.)

[9] At some time of day, during some season, at some latitude—this isn’t scientific, just handy!

Thus, a “plus” setting of the exposure compensation control increases the exposure given for any given measured scene brightness (smaller values of Av and/or Tv produce greater exposure.)

The amount of exposure compensation is quite properly described in the same “units” as Ev. As a result, the exposure compensation setting is often called the “Ev setting”. This is not a good description. It in fact does not set Ev, but rather forces the recommended Ev (even if only presented as a set of combinations of t and N) to be different from what would ordinarily be put into effect by the metering system. “Ev offset” is a better description. In technical contexts, exposure compensation is often called “exposure bias”.

8.1 Scene brightness in Ev?

We often see, especially in camera specifications, a factor that seems to be scene luminance (brightness) but described in terms of an Ev number. Such a factor might be, for example, the lowest scene luminance for which the exposure metering system of the camera is said to be able to function reliably.

This usage is unfortunate and technically inappropriate, as Ev is a measure of exposure, not luminance. There is a perfectly good APEX quantity for luminance: Bv. I suspect the motive for the practice is that many photographic enthusiasts have heard of Ev but not Bv.

Of course, if we know the Ev that a camera’s metering system recommends for a scene, we can in fact equate that to scene luminance if we also know the ISO sensitivity (Sv) in effect.[10]

It turns out that, when a manufacturer states some critical scene luminance in terms of “Ev”, and nothing to the contrary is stated, it is most often based on the assumption that the ISO sensitivity is ISO 100 (Sv 5). (Canon, for example, so states explicitly.) In other words, the luminance being described is that which, if the ISO sensitivity of the camera were ISO 100, would lead to the camera arranging for an exposure of the stated Ev (or a meter recommending an exposure of the stated Ev).

The relationship between this irregular description of scene luminance in “Ev” and the description of that luminance in the proper value, Bv, is as follows:

$$Bv = Ev' - 5 \tag{9}$$

where Ev’ is the so-called “Ev” used to describe the luminance.[11]

I discourage this usage.

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[10] And, to be precise, the metering constant, K, employed in the calibration of that camera.

[11] Note that the precise result depends on the value of C for the camera’s exposure metering system.

8.2 Ev "units" for everything

There is another practice which is not technically appropriate but doesn't actually give "wrong" information. Sometimes a camera manufacturer, stating the range of aperture available on a certain model, will say, for example: "f/2.8 through f/11, in 1/3 Ev steps". Of course, aperture is defined in terms of Av, not Ev. And APEX values are dimensionless and unitless, so a change in any one of them in the mentioned increment is just in steps of "1/3" (we might say, "1/3 unit").

But, in defense of the practice, a 1/3 unit change in Av does give a 1/3 unit change in Ev. Perhaps the motive for the practice is that many photographic enthusiasts have heard of Ev but not Av.

Still, a better practice would be so say, if we feel we must state a "unit", "f/2.8 through f/11, in 1/3 stop steps". (*Stop* is widely used in photographic photometry as the "unit" of a change in a factor affecting, or relating to, exposure.[12])

8.3 Another caution

The author has seen a number of monographs and charts explaining APEX in which the concepts of *luminance* (brightness) and *illuminance* (illumination) were confused. Sometimes there will be a perfectly good Iv table labeled "Bv", or vice-versa. Sometimes discussions of *luminance* will mention the units that are applicable to *illuminance*, or vice-versa. Please be cautious before undertaking any strenuous intellectual exercise in this area where there is a risk of such misinformation.

8.4 APEX notation for non-APEX quantities

Sometimes we will see it stated that in a particular situation, "Av was f/5.6" or "Tv was 1/60 sec". In fact, these APEX designations should only be used for the expression of these exposure factors in APEX (logarithmic) form.

A related problem occurs in connection with Canon cameras. Many of these have "aperture priority" and "shutter priority" exposure modes, in which the mentioned exposure factor is set directly by the user and the mating one is then set by the metering system to achieve the exposure (Ev) the system thinks appropriate. The two modes are labeled "Av" and "Tv", respectively. Yet the factors are set not in terms of APEX values but in conventional form ("f/3.5" or "1/125 sec"). What gives here?

Here's my guess: initially, on the Canon models offering these modes, the factors were indeed set in terms of the APEX units (in vogue at the time), and the modes were named correspondingly. Later, when awareness of APEX among photographers faded (or actually, didn't really flourish), Canon reverted to labeling the scales for setting aperture and shutter speed in the traditional units, but opted (for continuity) to retain the Av and Tv designations for the modes. Just a guess.

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[12] However, in many standards and learned papers, the term "step" is used for an increment of 2:1 in an exposure factor (presumably "stop" was considered too colloquial). That sadly leads to such unfortunate locutions as, "The aperture may be set to f/2.8 through f/22, in steps of 1/3 step".

9 LIGHT VALUE, Lv

Sometimes we encounter what sounds like a related concept involving the quantity *light value* (Lv). What's with that?

Today we mostly encounter this term as used by some authors as a replacement for "Ev" to unambiguously designate a logarithmic measure of scene luminance (the "Ev assuming ISO 100" convention). It's certainly better than calling the measure "Ev", but there is no need for this coinage, as a perfectly appropriate logarithmic measure of scene luminance exists: Bv.

There was an earlier use of the term "light value" (again symbolized as "LV"). On the first Polaroid Land camera, the Model 95, and the first "smaller film" Land camera, the Model 80, exposure was set with a single dial marked in terms of a number Polaroid called *light value*, symbolized LV. This is a logarithmic measure of exposure conceptually identical to exposure value (Ev) but with the scale starting at a different point (such that LV 1 = Ev 10).

The Polaroid exposure meter was set for the sensitivity (ISO speed) of the film in use, and then issued its exposure "recommendation" as an LV number. The user set this on the camera.

There was no provision for setting shutter speed and aperture separately. Each LV setting called up a preordained combination of shutter speed and aperture (an early example of "programmed exposure).

As the APEX system neared completion, Polaroid switched (in the successor models 95B and 80A) to the use of an Ev scale for exposure setting. This allowed consistency with other APEX-aware exposure meters, and the later Polaroid meters had Ev scales as well as LV scales (Ev scales only after a while).

Light value (LV), in either sense, is not part of APEX.

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APPENDIX A

Equations defining the APEX values

These equations are as given (for historical reference) in the appendix to standard ASA PH3.49-1971.

As elsewhere in this article I will use this notation: "Av" (lower-case "V"") rather than the more formal one: "A_V" (upper-case "V", subscript).

In these formulas I have used the accepted scientific symbols for, luminance (*L*) and illuminance (*E*), It the cited reference documents, other symbols are used.

But for aperture, where *N* is a common scientific symbol, I will retain "A", as in the published formulas, since in them N is used with an entirely different meaning.

For aperture value, A_v:

$$\mathrm{Av} = 2\log_2 A \qquad (10)$$

where *A* is the f/number.

But the f-numbers shown in the usual tables are the nearest value to the theoretical values for that A_V from the standard list of apertures at nominally one stop intervals.

For time value, T_V:

$$\mathrm{Tv} = -\log_2 t \qquad (11)$$

where *t* is the exposure time (shutter speed) in seconds, or, alternatively, by:

$$\mathrm{Tv} = \log_2 D_t \qquad (12)$$

where D_t is the denominator of the shutter speed in seconds.

But the values shown in the usual tables are the nearest values to the theoretical values for that T_V from the standard list of exposure times at one stop intervals.

For speed value, S_V:

The commonly used equation is:

$$\mathrm{Sv} = \log_2 \frac{S}{3.125} \qquad (13)$$

where *S* is the ISO speed rating (formerly the ASA speed rating).

Formally, the equation is given as:

$$\mathrm{Sv} = \log_2 NS \qquad (14)$$

where the constant *N* is defined (as exactly 0.3[13]) by ASA standard PH2.5-1960, which defines a relationship between "arithmetic" and "logarithmic" expressions of film sensitivity ("speed"), the latter of which is the progenitor of the APEX value S_V.

That can be rewritten as:

$$Sv = \log_2 \frac{S}{3.3333} \qquad (15)$$

Nevertheless, to lead to a more tidy series of values for integral values of S_V, the form seen above as equation 13 has been adopted for practical use.

Note for future reference that the equation in practical use (equation 13) implies a value of N of exactly 0.32.

What is the role of the constant N? It essentially establishes the "origin" of the scale of Sv, which is conceptually subject to arbitrary determination. Why was the value 0.3 chosen for N? The reason for that is lost in the fog of history. As we can see, it leads to an "untidy" relationship between Sv and the actual speed values.

Standard PH2.5-1960 gives defining equations for the "arithmetic" (and "logarithmic"[14]) speed ratings, as functions of a certain photometrically-determined property of the film, Em. But then it actually gives a standard list "standard" speeds (in "arithmetic" form), and in a table assigns each to a stated range of E_m. A second table gives a list of standard speeds (in logarithmic form) and again assigns each to a stated range of E_m. The table of "arithmetic" speeds has members that are nominally 1/3 stop apart; the table of "logarithmic" speeds has members that are nominally 1/2 stop apart.

Thus we cannot attempt to relate all the standard "arithmetic" speeds to corresponding "logarithmic" speeds. But is seems reasonable to try and relate (a) the subset of "arithmetic" speeds comprising every third one (separated by nominally one stop) with (b) the subset of "logarithmic" speeds comprising every other one (also separated by nominally one stop). That is, we would consider ASA 100 to be equivalent to ASA 5°.

When we compare these evidently "matching" speed ratings, we see that, for these tables, the underlying relationship between "arithmetic" ad "logarithmic" expressions of film speed is an equation in which N=0.32, not 0.3 (as we see here as equation 13).

The difference is slight, about 0.093 stop.

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[13] It is said that the original intent was that $N=2^{(-7/4)}$ (approximately 0.2973), but I am unable to reconstruct that or what happened later.

[14] The "logarithmic" speed rating here is the progenitor of the APEX value Sv.

This oddity can be traced to the approach used in the tables of PH2.5-1960 for assigning speed ratings to ranges of E_m which have been rounded to a granularity of 0.10 (for the "arithmetic" table) or 0.15 (for the "logarithmic" table).

For brightness value, Bv:

The commonly used equation is:

$$\mathrm{Bv} = \log_2 L \tag{16}$$

where L is the luminance (brightness) in footlamberts. For luminance in cd/m^2, that becomes:

$$\mathrm{Bv} = \log_2 \frac{L}{3.426} \tag{17}$$

The formal equation is

$$\mathrm{Bv} = \log_2 \frac{L}{NK} \tag{18}$$

where L is the luminance, N is a constant (with exact value 0.3, as described earlier), and K is the embedded *reflected light metering constant* (with a value suitable for L in footlamberts or cd/m^2, as appropriate).[15] Thus we can rewrite the equation for luminance in cd/m^2 as:

$$\mathrm{Bv} = \log_2 \frac{L}{1.028K} \tag{19}$$

The commonly-used equation implies a value of K of 3.33 for luminance in footlamberts, 11.4 for luminance in cd/m^2.

For incident light value, Iv:

The commonly used equation is:

$$\mathrm{Iv} = \log_2 \frac{E}{6.125} \tag{20}$$

where E is the incident illuminance (illumination) in footcandles. For illuminance, E, in lux, this is:

$$\mathrm{Iv} = \log_2 \frac{E}{68.90} \tag{21}$$

The formal equation is

$$\mathrm{Iv} = \log_2 \frac{E}{NC} \tag{22}$$

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[15] The presence of N in this equation is to recognize the definition of Sv, the speed value, which involves N. Of course, the definition of Sv in practical use implies a value of 0.32 for N.

where E is the illuminance, N is a constant (with value 0.3, as described earlier), and C is the incident light metering constant (with a value suitable for E in footcandles or lux, as appropriate).

The commonly-used equations imply a value of C of 20.8 for luminance in footcandles, 224.2 for luminance in cd/m^2.

For exposure value, Ev:

$$\mathrm{Ev} = \mathrm{Tv} + \mathrm{Av} \quad (23)$$

therefore:

$$\mathrm{Ev} = -\log_2 \frac{t}{A^2} \quad (24)$$

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