

# CORRECTION

## American National Standard for General-Purpose Photographic Exposure Meters (Photoelectric Type) PH3.49-1971

On page 8, the formula in Table 1 should read as follows:

$$\begin{aligned} 2E_v &= \frac{A^2}{T} \\ &= \frac{BS}{K} = \frac{IS}{C} \\ K &= \frac{K_0 r}{t} \end{aligned}$$

On page 15, Table A1 should read as follows:

Table A1  
Arithmetic and Additive (APEX) Nomenclature for Exposure Parameters

Arithmetic System		Additive (APEX) System	
$E_v$ = exposure value	$2E_v = \frac{A^2}{T}$ $= \frac{BS_x}{K}$ $= \frac{IS_x}{C}$	$E_v$ = exposure value	$E_v = A_v + T_v$ $= B_v + S_v$ $= I_v + S_v$
$T$ = effective shutter time, in seconds		$T_v$ = time value	$2T_v = \frac{1}{T}$ $T_v = 3.32 \log_{10} \frac{1}{T}$
$A$ = actual $f$ -number of lens diaphragm		$A_v$ = aperture value	$2A_v = A^2$ $A_v = 3.32 \log_{10} A^2$
$S_x$ = American National Standard Speed (of film)†		$S_v$ = American National Standard Speed value	$2S_v = NS_x$ $S_v = 3.32 \log_{10} NS_x$
$B$ = field luminance, in footlamberts		$B_v$ = luminance value	$2B_v = \frac{B}{KN}$ $B_v = 3.32 \log_{10} \frac{B}{KN}$
$K$ = exposure constant (reflected light)			
$C$ = exposure constant (incident light)			
$I$ = incident light, in footcandles (illuminance)		$I_v$ = incident-light value	$2I_v = \frac{I}{CN}$ $I_v = 3.32 \log_{10} \frac{I}{CN}$
		$N = 0.30^*$	

\*The value of  $N$  is established in American National Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous-Tone), PH2.5-1960. It is a constant which was chosen to establish the relation between  $S_x$  and  $S_v$ , shown in Table A2.

†The abbreviated designation of American National Standard Speed,  $S_x$ , may be written as, for example, ASA 25, and that for  $S_v$  may be written ASA 3°. (The degree symbol [ ° ] is used with the additive [logarithmic] film speed value.)

## Appendixes

(These Appendixes are not part of American National Standard for General-Purpose Photographic Exposure Meters (Photoelectric Type), PH3.49-1971, but are included for information purposes only.)

### Appendix A

#### The Arithmetic and Additive (APEX) Systems of Exposure Units

The additive (APEX) system of exposure units included in American National Standard PH2.12-1961 has not been used on consumer products and is omitted from

this revision. However, since it has been found useful in engineering, it is repeated in this Appendix for reference (see Tables A1 and A2).

Table A1  
Arithmetic and Additive (APEX) Nomenclature for Exposure Parameters

Arithmetic System		Additive (APEX) System	
$E_v$ = exposure value	$2E_v = \frac{A^2}{T}$ $= \frac{BS_x}{K}$ $= \frac{IS_x}{C}$	$E_v$ = exposure value	$E_v = A_v + T_v$ $= B_v + S_v$ $= I_v + S_v$
$T$ = effective shutter time, in seconds		$T_v$ = time value	$2T_v = \frac{1}{T}$ $T_v = 3.32 \log_{10} \frac{1}{T}$
$A$ = actual $f$ -number of lens diaphragm		$A_v$ = aperture value	$2A_v = A^2$ $A_v = 3.32 \log_{10} A^2$
$S_x$ = American National Standard Speed (of film)†		$S_v$ = American National Standard Speed value	$2S_v = NS_x$ $S_v = 3.32 \log_{10} NS_x$
$B$ = field luminance, in footlamberts		$B_v$ = luminance value	$2B_v = \frac{B}{KN}$ $B_v = 3.32 \log_{10} \frac{B}{KN}$
$K$ = exposure constant (reflected light)			
$C$ = exposure constant (incident light)			
$I$ = incident light, in footcandles (illuminance)		$I_v$ = incident-light value	$2I_v = \frac{I}{CN}$ $I_v = 3.32 \log_{10} \frac{I}{CN}$
		$N = 0.30^*$	

\*The value of  $N$  is established in American National Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous-Tone), PH2.5-1960. It is a constant which was chosen to establish the relation between  $S_x$  and  $S_v$ , shown in Table A2.

†The abbreviated designation of American National Standard Speed,  $S_x$ , may be written as, for example, ASA 25, and that for  $S_v$  may be written ASA 3°. (The degree symbol [ ° ] is used with the additive [logarithmic] film speed value.)

Table A2  
Values of Corresponding Exposure Parameters in Arithmetic and Additive (APEX) Systems\*

Time		Aperture		Film Speed		Luminance†		Incident Light‡		Exposure	
<i>T</i>	<i>T<sub>v</sub></i>	<i>A</i>	<i>A<sub>v</sub></i>	<i>S<sub>x</sub></i>	<i>S<sub>v</sub></i>	<i>B</i>	<i>B<sub>v</sub></i>	<i>I</i>	<i>I<sub>v</sub></i>	<i>A<sup>2</sup>/T</i>	<i>E<sub>v</sub></i>
1	0	1	0	3	0°	1	0	6	0	1	0
1/2	1	1.4	1	6	1°	2	1	12	1	2	1
1/4	2	2	2	12	2°	4	2	25	2	4	2
§ 1/8	3	2.8	3	25	3°	8	3	50	3	8	3
1/15	4	4	4	50	4°	16	4	100	4	16	4
1/30	5	5.6	5	100	5°	32	5	200	5	32	5
1/60	6	8	6	200	6°	64	6	400	6	64	6
1/125	7	11	7	400	7°	125	7	800	7	125	7
1/250	8	16	8	800	8°	250	8	1 600	8	250	8
1/500	9	22	9	1 600	9°	500	9	3 200	9	500	9
1/1000	10	32	10	3 200	10°	1000	10	6 400	10	1 000	10
				6 400	11°	2000	11	12 500	11	2 000	11
				12 500	12°	4000	12	25 000	12	4 000	12
										8 000	13
										16 000	14
										32 000	15
										64 000	16
										125 000	17
										250 000	18

\*For nomenclature, see Table A1.

†Luminance for  $K = 3.3333$ .

‡Illuminance for  $C = 20.83$ . Incident light is measured in the plane of the subject perpendicular to the direction of the camera.

§ The tabular values of  $T$ ,  $A$ ,  $S_x$ ,  $B$ , and  $I$  are rounded off to a uniform series of numbers which are easy to remember. However, the actual numbers to be used in designing and calibrating equipment are in a power-of-2 geometric progression starting with the precise values of the figures on the fourth line. The precise values of  $f/2.8$  is  $\sqrt{8}$ . The precise value of  $S_x$  25 =  $32/\sqrt{2} = 25.4$ . According to the formulas in Table A1, the precise equivalent of  $S_v$  3 is  $S_x$  25 = 26.7. Since APEX values are intended to be precise, the tabular luminance figures are based on  $S_x$  25 = 26.7 and  $K = 3.333$ .

NOTE: If intermediate subdivisions are used, square-root-of-2 steps are preferred for all parameters except  $S_x$ . Cube-root-of-2 steps are preferred for these arithmetic speeds in accordance with American National Standard Method for Determining Speed of Photographic Negative Materials (Monochrome, Continuous-Tone), PH2.5-1960.

## Appendix B

### Primary Standard for Color Temperature

#### B1. General

The primary standard for color temperature of 4700 K radiation consists of a tungsten lamp operated at 2854 K in combination with the Davis and Gibson filter. This source not only matches closely the spectral-energy distribution of a blackbody at 4700 K, but is also reproducible from specifications.

#### B2. Filter

The constituents shown in Table B1 are present in the indicated amounts in all filters.

The transmission of the filter is 0.259.

(These specifications have been contributed by Mr Raymond Davis)

#### B3. Construction of Filter

The construction of the filter holder and general instructions for preparation are given in *Filters for the Reproduction of Sunlight and Daylight and the Determination of Color Temperature*, National Bureau of Standards Miscellaneous Publication No. 114, 1931.

Table B1  
Filter Formulas

Solution A	
Copper sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ )	2.377 g
Mannite [ $\text{C}_6\text{H}_8(\text{OH})_6$ ]	2.377 g
Pyridine ( $\text{C}_5\text{H}_5\text{N}$ )	30.0 ml
Water (distilled) to make	1000 ml
Solution B	
Cobalt ammonium sulfate [ $\text{CoSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ ]	21.045 g
Copper Sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ )	15.642 g
Sulfuric acid (specific gravity 1.835)	10.0 ml
Water (distilled) to make	1000 ml

## Appendix C

### Exposure Parameters

#### C1. Relationship Between Sensitometric Exposure and Camera Exposure

The American National Standard film speed  $S_x$  expressed in terms of the sensitometric test exposure  $E_m$  is:

$$S_x = n/E_m \quad (\text{Eq C1})$$

where

$$n = 8^*$$

$E_m$  = exposure required to obtain the density used in determining the American National Standard Speed

Exposures are expressed in lux-seconds. The exposure  $E_g$  as determined by the exposure meter is:

$$E_g = I_o T \quad (\text{Eq C2})$$

where

$T$  = effective time of the shutter in seconds

$I_o$  = illuminance of the film, by the average field luminance measured by the exposure meter, in lux (metercandelas)

In order for a meter to be used to set a camera to the proper exposure, the following relationship is assumed to exist:

$$\frac{E_g}{E_m} = \text{constant} \quad (\text{Eq C3})$$

To write this relationship in a usable form, Equation C1 is substituted in Equation C3 to obtain the film exposure in the camera in terms of the American National Standard film speed. Thus,

$$E_g = K_1/S_x \quad (\text{Eq C4})$$

This factor  $K_1$  has been determined experimentally by psychometrically selecting the "preferred exposure" for scene types, light levels, and camera and meter types covering the ranges normally encountered. Its value for the purpose of designing a specific exposure control is dependent upon three variables: the spectral characteristics of the photodetector, the photographic

effectiveness of the scene illuminant, and the distribution of luminance levels in the scene as measured by the detector.

#### C2. Luminance Distribution Factor

The luminance distribution factor ( $R$ ) is defined by Equation C5. This factor is of importance when the background luminance within the field is radically different from the subject luminance. In this kind of scene, a meter reading of the integrated luminance ( $B_a$ ) of the whole scene may not lead to the best picture. The best picture would be obtained by setting into the meter's calculator a reading based on some other luminance value  $B_d$ , and giving the exposure directed by the calculator. Thus,

$$R = \frac{B_a}{B_d} \quad (\text{Eq C5})$$

where

$B_d$  = value of luminance which would lead to the best picture

$B_a$  = field luminance as measured by the meter

For the average scene, the factor ( $R$ ) can be assumed to be unity.

#### C3. Spectral Considerations

The spectral response of the film and the detector as well as the spectral quality of the light in the scene, and the light used in calibration and sensitometry, affect the meter calibration. If one factor ( $r$ ) is chosen to relate the photocell's spectral response to the scene as compared to that in calibration, and a second factor ( $p$ ) is used to relate the film's spectral response between scene and the sensitometric evaluations, these factors can be combined with ( $R$ ) into the constant  $K_1$  of Equation C4. These factors are defined as follows:

Firstly,  $r$  = ratio of luminance of uniform surface source used in calibration to luminance of scene when both sources produce the same response of the meter.

Since the calibration color temperature of 4700 K was chosen to minimize the spectral effect of indicated

\*See American National Standard Method for Determining Speed of Reversal Color Films for Still Photography, PH2.21-1961.

luminance in daylight compared to the indicated luminance for tungsten, the spectral response ratio determined between 4700 K and 2850 K is reasonable measure of the effect of difference in spectral sensitivity between daylight and the 4700 K calibration sources.

Secondly,  $p$  = ratio of the photographic effectiveness (activity) of scene illuminance to the photographic effectiveness of illuminance used in determining film speed.

It is now possible to define a basic constant  $K_1$  which excludes all variables except film speed  $S_x$  and camera exposure  $E_g$  due to measured field luminance.  $K'_1$  is defined as the value of  $K_1$  when:

$$r = 1.0$$

$$p = 1.0$$

$$R = 1.0$$

Equation C4 may be modified by substituting the above parameters to obtain:

$$E_g = K'_1 \frac{r}{p S_x R} \quad (\text{Eq C6})$$

#### C4. Relation Between Basic Exposure Parameters

Equation C6 may then be modified by substituting Equation C2 for  $E_g$  in order to present it in terms of the basic exposure parameters. Thus,

$$I_o T = K'_1 \frac{r}{p S_x R} \quad (\text{Eq C7})$$

The classical camera image illuminance formula is:

$$I_o = \frac{B (U - f)^2 t C H \cos^4 \theta}{4 A^2 U^2} \quad (\text{Eq C8})$$

where

$B$  = average field luminance measured by the meter based on luminance of calibration source, lumens/square meter

$U$  = distance from lens to object

$f$  = focal length of lens

$t$  = lens transmittance

$C$  = camera flare correction factor

$H$  = vignetting factor

$\theta$  = angle of image point from axis of lens

$A$  = geometric  $f$ -number of lens

Substituting Equation C8 into Equation C7 and rearranging in a form compatible with the exposure meter equation results in the following:

$$\frac{TS_x B}{A^2} = \frac{4K'_1 U^2 r}{(U - f)^2 t C H \cos^4 \theta p R} \quad (\text{Eq C9})$$

The exposure meter equation is:

$$K = \frac{TS_x B}{A^2} \quad (\text{Eq C10})$$

where

$K$  = exposure meter calibration constant

Substituting Equation C9 into Equation C10 results in an equation containing all the factors influencing the value of the exposure constant:

$$K = \frac{4K'_1 U^2 r}{(U - f)^2 t C H \cos^4 \theta p R} \quad (\text{Eq C11})$$

#### C5. Assumed Values

The following values have been assumed for the parameters in Equation C11 in the interest of simplification. For any unusual design or use situations, the validity of each of these assumptions must be evaluated:

$$U = 80f \quad \left[ \left( \frac{U}{U - f} \right)^2 = 1.025 \right]$$

$$C = 1.03$$

$$H = 1.0$$

$$\theta = 12^\circ \quad (\cos^4 \theta = 0.916)$$

$$p = \text{actual value}$$

$$K'_1 = 8.2$$

$$R = 1.0$$

$$t = \text{actual lens transmittance}$$

$$r = \text{actual spectral response ratio of light detector}$$

In American National Standard PH2.12-1961, the following assumptions were made:

$$K = 35.8 \text{ when } B \text{ was in apostilbs}$$

$$= 3.33 \text{ when } B \text{ was in footlamberts}$$

$$t = 0.95$$

$$r = 1.05$$

$$p = 1.1$$

Combining these assumed values into the preceding equations gives a value of 8.2 for the basic constant  $K'_1$ . More recent information indicates that average values are more nearly:

$$t = 0.90$$

$$r = 1.0$$

$$p = 1.0$$

## APPENDIX

Since  $r$  and  $t$  are subject to change, it is desirable to establish a constant  $K_o$  which is not likely to be changed greatly as the above variables change. Therefore,  $K$  is defined as follows:

$$K = \frac{K_o r}{t} \quad (\text{Eq C12})$$

Using the above value, Equation C12 becomes:

$$K = \frac{35.5r}{t} \quad (\text{for 16mm and larger films}) \quad (\text{Eq C13})$$

Since the screen luminance is lower for 8mm films, it has been found that the preferred exposure is increased by approximately  $1/3 E_v$ . When this factor is taken into account, Equation C13 becomes:

$$K = \frac{44.1r}{t} \quad (\text{for 8mm and super 8 films}) \quad (\text{Eq C14})$$

## Appendix D

### Units and Values of Exposure Parameters

Table D1 shows the units and values of exposure parameters used in the following equation (see Table 1):

$$\frac{A^2}{T} = \frac{BS}{K} \quad (\text{Eq D1})$$

where

$$K = \frac{K_o r}{t}$$

The Table also compares the values of exposure parameters given in the previous edition of this standard with those in the present revision.

**Table D1**  
**Units and Values of Exposure Parameters Used in Equation D1**

Symbol	Parameter	Unit	Name	Values of Parameters	
				ANSI PH2.12-1961	ANSI PH3.49-1971
<i>A</i>	Relative aperture	<i>f</i> -number	—	Geometric <i>f</i> -number	Geometric <i>f</i> -number
<i>T</i>	Exposure time	Seconds	—	Actual value	Actual effective value
<i>S</i>	Film sensitivity	American National Standard Speed	—	Actual value	Actual value
<i>t</i>	Lens transmittance	—	—	0.95	Actual value
<i>r</i>	Spectral response factor	—	—	1.05	Actual value
<i>R</i>	Scene luminance distribution factor	—	—	1.0	1.0
Symbol	Parameter	Units of Field Luminance ( <i>B</i> )	Name	ANSI PH2.12-1961	ANSI PH3.49-1971
<i>B</i>	Field Luminance	—	—	Actual value	Actual value
<i>K</i>	Exposure constant	Lumens/sq meter	apostilb (asb)	35.8	39.2
		Candelas/sq meter	nit	11.4	12.4
		Lumens/sq ft	footlambert (fL)	3.33	3.64
		Candelas/sq ft	—	1.06	1.16
<i>K<sub>o</sub></i>	Basic exposure constant	Lumens/sq meter	apostilb (asb)	—	35.8
		Candelas/sq meter	nit	—	11.4
		Lumens/sq ft	footlambert (fL)	—	3.33
		Candelas/sq ft	—	—	1.06



## Appendix E

### Photometric and Illuminance Units

**Table E1**  
Conversion Factors for Luminance Units

Number of → Multiplied by ↘  Equals Number of ↓	Stilb	Lambert	Candela/ft <sup>2</sup>	Footlambert	Nit	Apostilb
Stilb (Candela/cm <sup>2</sup> )	1	$3.183 \times 10^{-1}$	$1.076 \times 10^{-3}$	$3.426 \times 10^{-4}$	$10^{-4}$	$3.183 \times 10^{-5}$
Lambert (Lumen/cm <sup>2</sup> )	3.1416	1	$3.382 \times 10^{-3}$	$1.076 \times 10^{-3}$	$3.1416 \times 10^{-4}$	$10^{-4}$
Candela/ft <sup>2</sup>	$9.290 \times 10^2$	$2.957 \times 10^2$	1	$3.183 \times 10^{-1}$	$9.290 \times 10^{-2}$	$2.957 \times 10^{-2}$
Footlambert (Lumen/ft <sup>2</sup> )	$2.919 \times 10^3$	$9.290 \times 10^2$	3.1416	1	$2.919 \times 10^{-1}$	$9.290 \times 10^{-2}$
Nit (Candela/meter <sup>2</sup> )	$10^4$	$3.183 \times 10^3$	$1.076 \times 10$	3.426	1	$3.183 \times 10^{-1}$
Apostilb (asb)(Lumen/meter <sup>2</sup> )	$3.1416 \times 10^4$	$10^4$	$3.382 \times 10$	$1.076 \times 10$	3.1416	1

**Table E2**  
Conversion Factors for Illuminance Units

Number of → Multiplied by ↘  Equals Number of ↓	Phots	Footcandles	Lux
Phots (Centimeter-candle)	1	$1.076 \times 10^{-3}$	$10^{-4}$
Footcandles	929	1	$929 \times 10^{-2}$
Lux (Metercandle)	$10^4$	$1.076 \times 10$	1

## Appendix F

### References to the Appendixes

DAVIS, R., and GIBSON, K. S. *Filters for the Reproduction of Sunlight and Daylight and the Determination of Color Temperature*, NBS Miscellaneous Publication No. M114, National Bureau of Standards, U.S. Department of Commerce. Washington, D.C.: Government Printing Office, 1931.

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WOLFE, R. N., and MILLIGAN, F. H. The relative photographic efficiency of certain light sources. *Journal of the Optical Society of America*, vol 43, no. 9, Sept 1953, pp 791-797.