The ANSI PH3.49-1971 Specification And the Myth of the 18% Light Meter Calibration

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1.0 Introduction

This paper presents information summarized from ANSI **Standard ANSI/ISO 2720-1974 (R1994), ANSI/NAPM IT3.302-1994**. The aforementioned standard is a revision and re-designation of **ANSI PH3.49-1971(R1987),** and for the purpose of this paper, will simply be referred to as, "The standard".

The title of the standard is, **"General Purpose Photographic Exposure Meters (Photoelectric Type) – Guide to Product Specification".** The purpose of the standard is to, *"make information available for the development, manufacture and test of photoelectric exposure meters".* It does not however cover the automatic or semi-automatic control of exposure employed in cameras.

The standard explains and documents that reflected light meters are calibrated by reference to, *"an area of known uniform luminance which covers completely the whole field of view of the meter",* and for incident light meters, *"by reference to a point source of light of known luminous intensity located on the meter axis".*

It is with specific regard to light meter calibration that this specification is of interest. There are many myths and misconceptiuons regarding how light meters are calibrated, specifically with regard to their use in correctly reproducing the density and tonality of the so-called, "18% Gray Card".

2.0 Light Meter Calibration & The Myth of 18% Gray

There is a long-standing photographic myth (propagated and espoused by the instructors at Brooks, and other photographic institutions), that exposure meters are suppose to be calibrated to correctly read, and reproduce the density of an 18% Gray card. Well, it just is not so! I know, it's what we all have been taught, and there are many who would swear on a stack of Ansel Adam's diaries that it's true. This subject has caused a great deal of confusion and misinformation to be imparted to many a young (and old) photographer, including myself. A careful study of the aforementioned standard will help to dispel this myth, and although the mathematical foundations of the standard are not all that complex, there are many missing conversion factors and constants that would help the reader in going through the calculations.

The standard was created by the manufacturers to provide the industry with a standard for how to build and test light meters (simple hand held kind). This standard is not mandatory, but is what most of the industry has agreed upon. Boiled down to its essence, the standard specifies that **light meters should be calibrated to about 12-13% gray, with an allowable error of plus or minus 1-2%.**

Why 12% Gray you might ask yourself. A light meter after all does not have any way of knowing how bright the subject really is, all it can measure is how much light the subject reflects towards the meter. To make a correct exposure recommendation, the meter (or more correctly, the manufacturer of the meter) has to make an assumption about how reflective the subject is. A reflectance of 12% has no theoretical basis (at least none that I know of), it is simply I believe, the measured average reflectance of an outdoor scene in the middle latitudes in midyear.

Have you ever wondered why Kodak has such a convoluted description on how to hold an 18% Gray Card? If one pointed it directly at the light source, it probably would reflect 18% of the light falling upon it. By holding the gray card at an angle to the light source, the apparent brightness of the card is reduced. If we assume the reflectance is 12%, then by holding the gray card at an angle to the light source would reduce its reflectance by 30%.

3.0 Specification Paragraphs

So the myth of the 18% Gray Card has been exposed. Lets examine the specification and see where the author came by his conclusion.

3.1 Specification Paragraph 6.1 (Nomenclature for Exposure Parameters)

In this paragraph, the exposure value (E_v) is defined by the following relationships:

(1) $$2^{Ev} = A^2/t \quad \text{or} \quad E_v = 3.32\mathrm{Log}_{10}(A^2/t)$$

Where:

T: is the effective exposure time (shutter speed) in seconds.
A: is the f/stop number

3.2 Specification Paragraph 6.2 (Calibration Formulae)

From this paragraph we learn that there are two (2) calibration constants, one for reflected meters, and the other for incident meters. The calibration constants, **K** and **C** are defined by the following relationships:

(2) $K = LtS/A^2$ for reflected light meters

(3) $C = EtS/A^2$ for incident light meters

Where:

L: is the **Luminance** of the diffusing source (for reflected meters) measured in Candelas per square meter (Cd/m^2)

E: is the **Illumination** from a point source (for incident meters) measured in Lumens per square meter ($Lumen/m^2$ – or LUX)

T: is the effective **exposure time** (shutter speed) in seconds.

S: is the ISO **film speed**

3.3 Combining Equations 1, 2, & 3

By combining equations 1,2, and 3 presented in this paper we can show the following relationships:

(4) $$2^{Ev} = A^2/t = LS/K = ES/C$$

and also:

(5) $$K/C = L/E$$

Equation 5 is the 1st clue and shows that the ratio of the constants K and C is the same as the ratio of the reflected light and the incident light. Recall what 18% gray means.

3.4 Specification Paragraph 6.3 (Calibration Constants)

In specification paragraph 6.3 the calibration constant values for K and C are presented for both Hemispherical (Cardioid) and flat (Cosine) type receptors and are summarized here:

(6) $$K_1 = 10.6 \text{ to } 13.4\ Cd/m^2$$

(7) $$K_2 = 10.3 \text{ to } 16.9\ Cd/m^2$$

Where: 1) is a hemispherical receptor
2) is a flat receptor

And values for C are as follows:

(8) $$C_{1a} = 320 \text{ to } 540\ Lumen/m^2$$

(9) C_{2a} = 400 to 680 Lumen/m^2
(10) C_{1b} = 240 to 400 Lumen/m^2
(11) C_{2b} = 300 to 500 Lumen/m^2

Where: “a” is a hemispherical receptor, and “b” is a flat receptor.

3.5 Some Conversion Factors Missing From The Specification

Recall from equation (5) that we are very interested in the ratio of K & C (K/C). In order to make this calculation, both the constants K and C must be expressed in compatible units of measure. In the specification, K is expressed in Candelas per square meter (cd/m^2) and C is expressed in Lumen/m^2 . In order to make the ratio a dimensionless quantity, like a percentage, we must express K and C in compatible units of measure. To do this, we first need to present some conversion factors that the specification neglected to include.

Historically, reflected light has been measured in **footlamberts**, and incident light is measured in **footcandles**. When we calculate the ratio of K/C we will do so in these units of measure. Here is how footlamberts and footcandles are defined:

1 Footcandle = 0.0929 Lumens/m^2
1 Footcandle = 1 Lumen/f^2
1 LUX = 1 Lumen/ m^2 = 10.76 Footcandles
1 Footlambert = 1 Lumen/f^2
1 Footlambert = 0.3183 Candles/f^2
1 f^2 = 0.0929 m^2

3.6 An Example Calculation

Suppose for example we want to look at the ratio of K/C using a flat receptor. The values for K and C are again:

K_2 = 10.3 to 16.9 cd/m^2
C_{2b} = 300 to 500 Lumen/m^2

The mid-point values for each of these value ranges are:

K_2 = 15.1 cd/m^2
C_{2b} = 400 Lumen/m^2

Now we convert each constant into Footlamberts and Footcandles as follows:

K_2 = 15.1 cd/m^2 x (0.0929 m^2/f^2) x (1 Footlambert/(0.3181 cd/f^2))
K_2 = 4.4 Footlamberts

Now lets convert C_{2b} to footcandles as follows:

C_{2b} = 400 Lumen/m^2 x 0.0929 m^2/f^2
C_{2b} = 37.2 Lumens/ f^2
C_{2b} = 37.2 Footcandles (Remember 1 Lumen/f^2 = 1 Footlambert)

Now we can finally calculate the ratio of K/C for the flat receptor:

K/C = 4.4 Footlambert / 37.2 Footcandles = **11.8%**

So we can see using a flat receptor the ratio of K/C is approximately 12%, not 18%

3.7 An Example Calculation From Real Life

Now lets repeat this calculation, this time using values for the calibration constants K and C supplied to us by the vendor of one of the most commonly used light meters, the **Minolta Flash Meter** V. From the use's guide we find values for K and C as follows:

K = 14 cd/m^2
C = 330 Lumen/m^2

Doing the same conversions we get the following values:

K/C = 4.086 Footlambert / 30.7 Footcandles = **13.3%**

3.8 One Final Interesting Example Calculation From Real Life

Lets use equation 4 presented in this paper to validate the predictions for correct exposure that one would make when using the Basic Daylight Exposure (BDE) method.

Recall that BDE predicts that given an ISO film speed of say, 100, that the correct exposure for that film would be f/16 @ 1/100th of a second. Lets put this to the test.

From equation 4 we have:

$$\mathbf{2^{Ev} = A^2/t = LS/K}$$

A typical value for the Luminance of the bright Moon(2) (remember the BDE rule applies also for the correct exposure of the moon) is **2500 cd/m^2**. Lets also use the same value for K as we did in paragraph 3.7 (Minolta Light Meter): K=14 cd/m^2. The value for E_v that corresponds to a luminance of 2500 cd/m^2 is 14.1

(see the appendix for an explanation). Re-arranging equation 4 and solving for S yields:

$$\mathbf{S = K\ 2^{Ev}/L}$$

Or:

$$S = (14/2500) \times 2^{14.1} = \mathbf{98.3}$$

Recall that our ISO film speed in this example was 100, so we are not far off!

Bibliography

(1) ANSI Standard ANSI/ISO 2720-1974 (R1994), ANSI/NAPM IT3.302-1994. *"General Purpose Photographic Exposure Meters (Photoelectric Type) – Guide to Product Specification".*

(2) CRC Handbook of Chemistry & Physics, 52 Edition, CRC Press, 1972. Photometric Quantities, Units & Standards, Page E-185.

Appendix

E_v to Luminance Conversion Table (from the Minolta Spotmeter F manual)

E_v Integer	**cd/m^2**	**Footlamberts**
1	0.28	0.082
2	0.56	0.16
3	1.1	0.33
4	2.2	0.65
5	4.5	1.3
6	9.0	2.6
7	18	5.2
8	36	10
9	72	21
10	140	42
11	290	84
12	570	170
13	1100	330
14	**2300**	670
15	4600	1300
16	9200	2700
17	18,000	5400
18	37,000	11,000
19	73,000	21,000
20	150,000	43,000
21	290,000	86,000
22	590,000	170,000

E_v Decimal	**Mult. Integer Luminance by this factor**
0.0	1.00
0.1	**1.07**
0.2	1.15
0.3	1.23
0.4	1.32
0.5	1.41
0.6	1.52
0.7	1.62
0.8	1.74
0.9	1.87

From the example, a luminance of 2500 cd/m^2 is 1.087 larger than 2300 cd/m^2 (or E_v = 14). 1.087 is closest to 1.07 in the table above, with a corresponding decimal E_v value of 0.1. So a luminance of 2500 cd/m^2 is approximately 14.1 in E_v value.