The Weston Master family of photographic exposure meters

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ABSTRACT AND INTRODUCTION

An important family of photographic exposure meters is the Weston Master family. The series has a fascinating history with respect to the meters themselves and with respect to the firms involved. In this article I try to paint the overall picture of this family and its story, and describe the meters in it (actually starting with one that is just before the family proper). Basic background on the underlying technical theory of incident light exposure metering and other specialized technical information is given in an appendixes.

1. GENERAL

1.1 Background

Appendix A gives some background in Photographic Exposure Metering.

1.2 Incremental descriptions

When a certain feature is introduced at a particular model of the line, it will be discussed there. If there is no mention of this feature in the description of a following model, we may in general assume that it is still in play there.

1.3 Our personal collection

We have specimens of several of the meter models discussed here in our personal collection. These are indicated by a "smiley face" next to the main photograph of the model. The photo is not of our specimen unless indicated.

1.4 Photo credits

Many photos in this article are copyright James Ollinger, and are used by permission. Thanks, James. Thanks also to John D. de Vries for the use of his photographs.

1.5 Standard position

All the meters discusses here are intended to be held with their long axis horizontal, for the Weston Master models themselves with the indicating meter to the left. The orientation of the notation on the indicating meter is, with few exceptions, and often some of the markings on the fixed dials of the exposure calculator, are oriented to match that. Some of the manuals include illustrations of the "recommended grip".

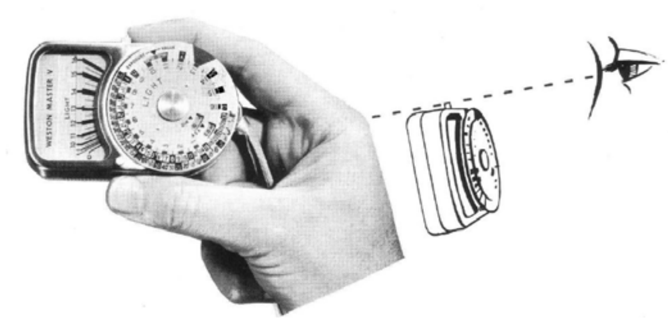

Figure 1. Holding the Weston Master V

The right-hand portion of the figure indicates that one should "sight" across the uppermost edge of the meter, and that, for outdoor work, ideally the meter should be tipped a little downward to avoid including too much skylight in its view.

However, when I describe the location of various features on the meters, for the Weston Master models I do so in terms of the meter in "vertical" orientation, the indicating meter at the top.

Here we see famed cinematographer Karl Struss using a Weston exposure meter of an unknown model.[1]

Figure 2. Cinematographer Karl Struss with Weston exposure meter

1.6 The light measurement system

All the meters described in this article use a selenium photovoltaic photocell, which generates an electrical voltage when exposed to

[1] Weston purists will note that this is the "left-handed" grip. This usage is in incident light mode, apparently with a "Type 1" Invercone on the meter (see section 3.).

light. Its output is directly read by a microammeter. No battery is involved.

1.7 The meter reading

These meters being primarily intended for reflected light metering, in which the property being measured is the luminance of the scene (or a closely-related property), the meter itself is marked in the luminance unit *candle per square foot*, even though that unit is not indicated (and is rarely even revealed in the manuals).[2]

1.8 The exposure calculator

As with most familiar photographic exposure meters, the Weston Master meters utilize an exposure calculator, a specialized circular slide rule, to "work the exposure equation" and deliver a photographic exposure recommendation.

There are a few special wrinkles to the Weston exposure calculators, and in any case the working of the calculator is of importance to this whole topic. Accordingly, an extensive discussion of the exposure calculator, as found on the Weston Master exposure meters, is found in Appendix B. Variations for particular models are discussed in the corresponding section.

2. THE WESTON MASTER SERIES EXPOSURE METERS

2.1 The Weston Model 650

We begin with a meter that is not actually part of the Master series, but is its immediate predecessor. It set the tone for many features of the Master line itself, and so I describe it here. This meter was introduced in 1935 and was manufactured until 1939. Figure 3 shows a typical specimen (there were a number of minor variations).

Figure 3. Weston Model 650 exposure meter—front view

The photocell is on the rear, as seen in figure 4.

[2] An exception is the Weston Master V, in which the meter reading is in arbitrary units, related logarithmically to luminance.

Figure 4. Weston Model 650 exposure meter—rear view

The "bees-eye" array of little lenses is used to give the meter the appropriate "field of view", which ideally should about match that of the camera. This arrangement is basically followed as well in all the meters of the Weston Master series proper.

Having the photocell on the far side of the instrument from the meter itself is a paradigm followed by the entire Weston Master series proper. This is in contrast to many other exposure meters, in which the instrument was held “flat” with the actual meter face up and the "business end" is on the far end of the housing.

As mentioned earlier, the meter proper reads in candles per square foot. The maximum readable value is 1000 candles per square foot.

There is no provision for extending the range. There is no provision for adapting the meter to incident light metering.

The exposure index was set into the emulsion speed window, and was in terms of the Weston system of film speed ratings. A Weston speed of 80 roughly corresponds to today's ISO 100.

The small "screw" on the face is used to adjust the zero position of the meter, the familiar arrangement long seen in electrical panel maters (Weston’s main business at the time).

2.2 The Weston Master (model 715)

2.2.1 *Basics*

Weston model 715 was called the Weston Master Universal Exposure meter. It was introduced in 1939 and made through 1945. Figure 5 shows a typical specimen (there were a number of variants).

Figure 5. Weston Master (model 715)

Note the orientation of the word "light" and of the meter scale numbers (although one might argue that the orientation of the numbers was just for "clearance"). Certain numbers on the exposure calculator were also made to read "from the left". This all reflects the "standard position" for the instrument, which was (held in the right hand, of course) with its long axis horizontal and the meter itself to the left. In fact, the rounded profile of the "calculator" end was intended to fit between the thumb and index finger of the right hand when holding it in that position.

2.2.2 *Range extension*

The basic illuminance range of the meter was to 1600 candles/ft^2. In the normal configuration, the exposure meter is covered by a plastic trap door (the "range extending baffle") with numerous small holes through it. This serves to attenuate the light on its way to the photocell by a factor of 32.

Figure 6. Weston Master—baffle half open

To operate at lower luminance levels than could accurately be read on the 0-1600 candles/ft^2 scale, this baffle is unlatched and folded back out of the way. (There is a detent that held it open.) Then the meter scale becomes 0-50 candles/ft^2. We see the arrangement (with baffle half open) in figure 6.

When the baffle is swung out of the way, a cam arrangement moves the meter scale plate so that a new set of numbers—0-50—come into view, reflecting the new scale.

Almost the identical arrangement was used on all the subsequent members of the Weston Master family.

2.3 The Weston Master II (model 735)

2.3.1 *General*

Weston model 735 was called the Weston Master II Universal Exposure meter. It was introduced in 1945 and made through 1953. Figure 7 shows a typical example.

Figure 7. Weston Master II (model 735)

This model is not dramatically different from the Weston Master except for an update in styling.

In figure 8 we see famed photographer Ansel Adams and his trusty Weston Master II.

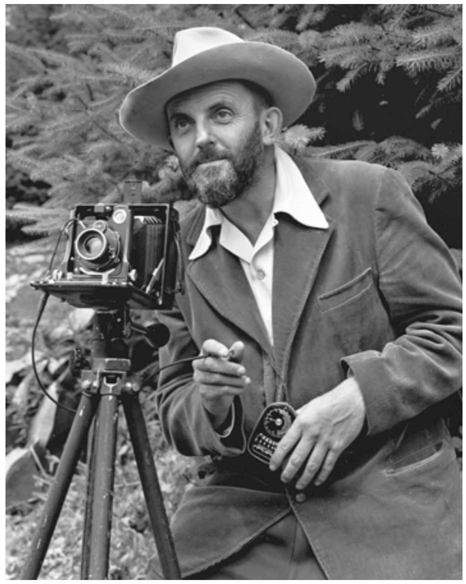

Figure 8.

2.3.2 *The exposure calculator*

The overall principle of the exposure calculator of the Weston Master II is as described in Appendix B. Dial Y is moved with a small tab adjacent to the exposure index window (marked "emulsion speed"; the setting was in the Weston system). But before it can be moved, a small button at the "bottom" of the dial (that is, the bottom if the meter were held vertically) must be pushed. That way the setting could not be accidentally changed.

This model was made in Newark, New Jersey by Weston Electrical Instrument Corp. for the American Market, but for the European market it was made (under a different model number) in Great Britain by Sangamo-Weston, a related firm.

2.3.3 *Incident light metering*

During the life of this model, provisions were made for it to be used in an incident light mode. The details are found in section 3. of this article.

2.3.4 *Zero adjust*

The zero adjusting "screw" is now on the rear of the meter, as weill be true of all subsequent models.

2.4 The Weston Master III (model 737)

Weston model 737 was called the Weston Master III Universal Exposure meter. It was introduced in 1956. Figure 9 shows a typical example.

Figure 9. Weston Master III (model 737)

The exposure index window is labeled "exposure index" and works in terms of the ASA speed, not the Weston film rating. There is no longer a lock on the exposure index dial.

The calculator, in addition to delivering its exposure recommendation in terms of matching sets of f-number and shutter speed, also reports in it terms of the Polaroid LVS (Light Value System) and in terms of "Light Value", a quantity that is essentially identical to the APEX *exposure value* (Ev.)

The topographical details of the calculator are changed compared to that on the Master II to make the dial less cluttered, and the overall calculator is slight larger in diameter.

With regard to the U-A-(B)-C-O markings, there are now dots at one-stop intervals between U and A and between C and O. These facilitate making "exposure compensation" settings greater than ±1 stop.

2.5 The Weston Master IV (model 745)

2.5.1 *General*

Weston model 745 was called the Weston Master IV Universal Exposure meter. It was introduced in 1960. Figure 9 shows a typical example.

Figure 10. Weston Master IV (model 745)

2.5.2 *The exposure calculator*

The exposure index window is labeled "ASA" and works in terms of the ASA speed, not the Weston film rating. There is no lock on the exposure index dial, which is turned by grasping a small post on it.

The calculator, in addition to delivering its exposure recommendation in terms of matching sets of f-number and shutter speed, also reports it in terms of the "Exposure Value System (EVS), a quantity that is essentially identical to the APEX *exposure value* (Ev.)

None of the markings on any of the dials are oriented to be optimally read with the meter in "standard position".

2.5.3 *The pointer lock*

A slide "switch" on the right side of the meter can be moved to lock the meter needle in its current position. Thus, when the meter is properly aimed at the scene, the user can lock the meter indication, which can then be "read" with the meter moved to a convenient position.

2.5.4 *Incident light metering*

This model may be used in an incident light mode, two different accessories for such being available over its lifetime. The details are found in section 3. of this article.

2.6 The Weston Master V (model 748)

2.6.1 *General*

Weston model 748 was called the Weston Master IV Universal Exposure meter. It was introduced in 1964. Figure 11 shows a typical example.

Figure 11. Weston Master V (model 748)

Unlike earlier models in the family, here the meter reading is not in terms of candles/ft^2 but rather in arbitrary numbers (albeit with a logarithmic relationship to the luminance).

Unlike earlier models in the family, the numbers on the meter scale were oriented to be read with the held vertically. (The change to small arbitrary numbers on the meter scale may have been done for best compatibility with this arrangement.) Some of the shutter speed markings on the fixed dial of the exposure calculator, however, are still oriented to be read optimally with the meter in "standard position" (but not those in the range 1/125 through 1/1200 second, which wouldn't fit that way).

2.6.2 *The exposure calculator*

The exposure index windows are labeled "ASA" and "DIN" and work in terms of ASA speed or DIN degree.

To set the exposure index, a small release button (located at about 10 o'clock on the outside of the dial) is pressed and the main dial turned until the desired ASA speed (or DIN degree) appears in the corresponding window.

The calculator, in addition to delivering its exposure recommendation in terms of matching sets of f-number and shutter speed, also reports it in terms of the APEX *exposure value* (Ev.)

2.6.3 *The pointer lock*

If the user wishes, the meter can be arranged so that the meter needle is locked in place unless a small button on the right side of the meter is depressed. Then, when the meter is properly aimed at the scene, the user can press and then release the button, capturing the meter indication, which can then be "read" with the meter moved to a convenient position. If this feature is not desired, the button can be pushed down and turned to lock it in the "always free" position.

2.7 The Weston Euro-Master (model S461-6)

Weston model S461-6 was called the Weston Euro-Master Universal Exposure meter. It was introduced in 1972 for European markets only. Figure 9 shows a typical example.

Figure 12. Weston Euro-Master (model S461-6)

This model was manufactured by Sangamo-Weston until 1980. This model is almost identical to the Western Master V. One change is that the numbers on the meter were arranged to read properly when the meter was held in the "standard position". But the shutter speed indications on the fixed ring of the calculator are not arranged to be optimally read with the meter in "standard position".

2.8 The Euro-Master

In 1980, Sangamo-Weston discontinued manufacture of the Weston Euro-Master. Its production (as the Euro-Master) was then taken over by East Kilbride Instruments of Scotland, until 1984, when that company went out of business. We see the Euro-Master in figure 13.

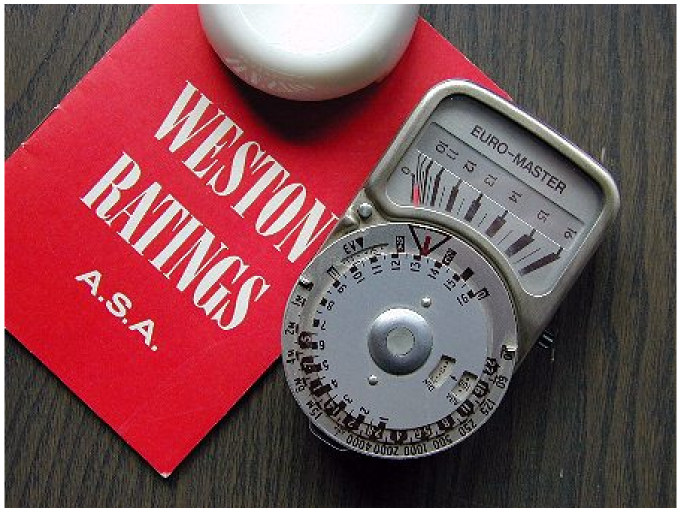

Figure 13. Euro-Master

Photo by John D. de Vries
Used by permission.

It is essentially indistinguishable from the Weston Euro-Master.

2.9 The Euro-Master II

This model was introduced by a company called Megatron in 1985, and was manufactured until about 2005. (Megatron ceased operations in 2010.) We see it in figure 14 (accompanied by its Type 2 Invercone).

Figure 14. Euro-Master II

Photo by John D. de Vries
Used by permission.

This model is almost identical to the Weston Master V.

2.10 The Weston Master 6 (model 560)

The Weston Master 6 (model 560) was introduced in 1972, but we don't know who made it. It was not made by any descendant of the Weston empire, but rather by some firm who somehow acquired rights to the "Weston Master" name. Figure 15 shows it.

Figure 15. Weston Master 6 (model 560)

Many students of the Weston Master family do not consider this model to be a legitimate member of it.

The overall design is very much based on that of the Weston Master V.

3. INCIDENT LIGHT EXPOSURE METERING

3.1 Introduction

Incident light exposure metering can be a valuable tool in attaining a "desirable" exposure result, especially for scenes in which the distribution of reflectance (and thus of luminance) is far from that assumed by the "reflected light exposure meting equation". It is often used by cinematographers and portrait photographers.[3]

In this mode, what the meter is intended to respond to is not the average scene luminance (over some field of view) but rather the illuminance[4] upon the subject.

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[3] A further discussion will be found in Appendix A.

[4] In some forms of the technique, it is not precisely the illuminance that is determined but rather a property that is much like it.

3.2 The incident light measurement diffuser

Typical incident light measurement instruments (whether for photographic exposure use or not) allow the illumination whose illuminance is to be determined to fall on a translucent "window" (often shaped as a shallow dome). This is characterized as an *incident light measurement diffuser*. This basically takes all the luminous flux that strikes it from different angles, "weights" it in accordance with its angle of arrival according to the meter's intended directivity pattern, and presents on its underside a luminous disk whose luminance is observed by the photocell.

3.3 Enter the Invercone

The Weston Master exposure meters are primarily intended for use in reflected light exposure metering. During the life of the Weston Master II, Weston decided it would be desirable for the meters to be able to be also used in the incident light mode. This may have in fact been partly motivated by the fact that there was great acceptance in the cinematography world of the competing Norwood Director meter, which was specialized for a particular form of incident light metering.

To that end, Weston made available for use with the Weston Master II an incident light measurement diffuser which they called the **Invercone**, a name based on the *inverted cone* that formed a key feature of its physical design. For ease in reference as this story unfolds, I call this a "type 1A Invercone". It is the white object seen in Figure 16.

To operate the meter in the incident light mode, the range-extending baffle is opened and the Invercone is snapped in place over the photocell,

After allowing the meter to observe the illuminance upon the subject, the meter reading is entered it the exposure calculator in the same was as for reflected light metering. The photometric transfer property of the diffuser was made such that the resulting photographic exposure recommendation would follow the intended value of C, the incident light exposure measurement calibration constant.

If the luminance were so great that to would exceed the range of the meter, we might think that the user could close the range-extending baffle before mounting the Invercone. But in fact, in this model of meter, with the baffle closed there was not sufficient space to mount the Invercone.

So the "type 1A" Invercone came with its own range-multiplying baffle, called the *auxiliary multiplier*. It is a plastic disk carrying an attenuating filter, and gives the same attenuation of light (1/64) as does the range-multiplying baffle. It can be placed in the "well" of the photocell before the Invercone is snapped in. In fact, it has two tabs that actuate the same lever that is pressed when the baffle is closed, so that with the auxiliary multiplier in place, the meter scale shifts to reflect the resulting higher range. A very clever design.

Figure 16 shows the auxiliary multiplier and then the type 1A Invercone being put in place on a Weston Master II.

Figure 16. "Type 1A" Invercone (white) and auxiliary multiplier (black) on a Weston Master II

Photo by Roger William Hicks and Frances Eugenia Schultz

The type 1A Invercone was also directly usable with the Weston Master III.

Invercone type 1A confers on the meter a directivity pattern very nearly that of the cosine pattern. Accordingly, the meter reading is based very nearly on the actual illuminance of the incident illumination.

Because of the influence of the meter housing on the pattern for directions toward the "lanyard" end of the meter, it is generally desirable when using the Invercone to hold the meter vertically.

3.4 The Weston Master IV

3.4.1 *Type 1B Invercone*

The Weston Master IV was designed so that an Invercone can be mounted with the range-multiplying baffle closed, thus eliminating the need for the auxiliary multiplier. The Invercone used was of a slightly different design in order to participate in this. I refer to this as a type 1B Invercone. Figure 17 shows an Invercone type 1B.

Figure 17. Invercone "type 1B"

Photo by John D. de Vries
Used by permission

The Invercone type 1B was also usable on the Weston Master V.

3.4.2 *Type 2 Invercone*

During the life of the Weston Master V, Weston introduced a quite-different design of Invercone, which I call the Invercone type 2. Figure 18 shows it mounted on a Weston Master IV meter.

Figure 18. Invercone "type 2" on Weston Master IV

The type 2 Invercone confers on the meter a quite-different directivity pattern, closely following the cardioid directivity pattern. This is also found with meters using a hemispherical incident light metering diffuser, as developed by Donald W. Norwood, and used in the "Norwood Director" series of incident-light exposure meters. It is often considered that, over many types of photographic scenes and lighting situations, such a directivity pattern gives, overall, the "most appropriate" photographic exposure recommendation.

Because of the use of other than a cosine directivity, the photometric property measured by the meter here is not strictly the illuminance of the incident illumination.

As with the Invercone type 1B, when a higher range is needed, the range-multiplying baffle can just be closed before the Invercone is mounted.

The type 2B Invercone can be used on a Weston Master IV meter.

Because of the influence of the meter housing on the pattern for directions toward the "lanyard" end of the meter, it is generally desirable when using the Invercone to hold the meter vertically.

4. CALIBRATION CONSTANTS

The calibration constants, K and C, are design parameters of an exposure meter. They determine what exposure recommendation the meter will issue for a certain measured scene luminance (for the reflected light mode) or incident illuminance (for the reflected light mode) plus a certain exposure index. K pertains to the reflected light mode and C to the incident light mode.

The international standard for free-standing photographic exposure meters "allows" a wide range for either K or C. This is because there is no inherently "correct" photographic exposure for any situation, and different manufacturers wish to be able to adopt different values of K and C based on their pragmatic, empirical thoughts as to what values will "make most users happy with the result most of the time".

Often today manufactures will adopt either 12.5 or 14 as the value of K, and perhaps 340 as the value of C.

For the Weston Master IV and V, the meter nameplate advises a value of 1.0 for K. This is in cd/ft^2 terms; in SI units (as used for the values mentioned above), that would be 10.8. This would lead to a lesser exposure recommendation than for example, a meter with a K of 12.5 (but only by less than 1/4 stop).

"Reverse engineering" of the exposure calculator for the Weston Master III suggests that the intended value of K there is (in SI units) is 10.6. (There is considerable opportunity for experimental error in this.)

We have not as yet ascertained the apparent values of C for any of these meters.

5. DIRECTIVITY PATTERNS

Appendix C shows the directivity patterns, as measured here, of a Weston Master V meter equipped with both the type 1A and type 2 Invercone.

6. Acknowledgements

Thanks to John D. de Vries for his extensive support in many ways of my learning about these exposure meters, and for the use of his excellent photos here.

His site has extensive information on the Weston Master line of exposure meters. Here is a good place to start:

http://www.johndesq.com/westonmaster

Thanks again to James Ollinger for the many fine photos and permission to use them, and for the wealth of information on his site about exposure meters. Much of my research was guided by that information.

His exposure meter site can be found here:

http://www.jollinger.com/photo/meters/meters/ge_dw68.html

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Appendix A

Basic Background in Photographic Exposure Metering

A.1 General

In photographic exposure metering, we use an instrument to measure either the light emitted by of reflected from the subject or the light falling on the subject, and from that, plus knowledge or assumption about the sensitivity of the film (or digital sensor) being used, the instrument issues a recommended photographic exposure, usually in the form of a collection of equivalent combinations of exposure time (shutter speed) and aperture (f-number). Two basic techniques are used.

Here is some basic information about this topic, pertinent to the discussions in the body of the article. It is beyond the scope of this article to discuss at length the details, relative advantages, and the limitations, of each technique.

A.2 Reflected light exposure metering

A.2.1 General

This is the technique used in most photography (especially "amateur" photography). In it, the instrument measures the average *luminance* of the scene (hopefully, with a field of view matching that of the camera). From that, plus the "exposure index" (what the photographer has told the meter is the sensitivity of the film or digital sensor), the meter issues a recommended photographic exposure.

The name of the technique comes from the fact that the luminance of the subject is often a manifestation of light reflected from it, although of course some subjects are self-luminous (the shade of a table lamp, for example).

A.2.2 The result

The result of a reflected light metered exposure (in a digital camera) is that the average photometric exposure on the sensor (over the entire image) is a certain fraction of the "saturation" photometric exposure. The fraction is largely a function of the value of K used by the meter (see section A.4).

A.2.3 Implications

The assignment of different photometric exposures (and thus different exposure results) to scene elements of different reflectance is dependent on the average reflectance of the scene.

One impact of this is often summarized thus: A photo of a white cat on a snowdrift comes out looking like a gray cat on an ash heap; a photo of a black cat on a coal pile comes out looking like a gray cat on an ash heap.

A.3 Incident light exposure metering

A.3.1 General

In this technique, simplistically, the meter determines the *illuminance* of the light that illuminates the subject (the *incident light*). From that, plus the "exposure index", the meter issues a recommended photographic exposure.

A.3.2 The result

The result of an incident light metered exposure is that, if all elements of the scene are equally illuminated, the photometric exposure given each element of the scene is proportional to its individual reflectance.[5] The exact proportional relationship is largely a function of the value of C used by the meter (see section A.4).

A.3.3 Implications

One impact of this technique is often summarized thus: A photo of a white cat on a snowdrift comes out looking like a white cat on a snowdrift; a photo of a gray cat on an ash heap comes out looking like a gray cat on an ash heap; a photo of a black cat on a coal pile comes out looking like a black cat on a coal pile.

A.4 Exposure equations and calibration constants

In each case, the development of a photographic exposure recommendation is done following a straightforward linear equation. The exact relationship between a certain combination of measured luminance or illuminance, plus a certain exposure index, and the issued photographic exposure recommendation is controlled by an *exposure metering calibration constant*, which has the symbol K for the reflected light mode and C for the incident light mode.

The greater the value of K [or C], then for a given average scene luminance [or illuminance on the scene], and a given exposure index, the greater will be the recommended photographic exposure.

No "correct" value for K or C can be derived mathematically, owing to the fact that there can be different "strategies" with regard to the

[5] This is very similar to the underlying concept of the "Zone System", a scheme of exposure planning popularized by famed photographer Ansel Adams and others.

desirable exposure result. Thus, over the years, exposure meter manufacturers have each chosen a value of K and or C for their exposure meters based on their own thoughts as to what value will produce exposure results they feel their users will most often enjoy.

That having been said, in recent decades, most exposure meter manufacturers have used fairly consistent values of K and/or C.

A.5 Directivity patterns

Of considerable importance to the specific performance of incident light exposure meters is the matter of the meter's *directivity pattern*. This is a plot, in polar coordinates, of the relative response of the meter to a light beam of any given "potency" for different angles of arrival of the beam.

Directivity patterns for the Weston Master V meter when placed in the incident light mode can be found in Appendix C.

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Appendix B

The Weston Exposure Calculator

B.1 Basics

All meter described here have what I will describe as the exposure calculator. This is a specialized circular slide rule that "works the exposure equation" for the user. I will describe it with reference to Figure 1, which shows the calculator of a Weston Master V.

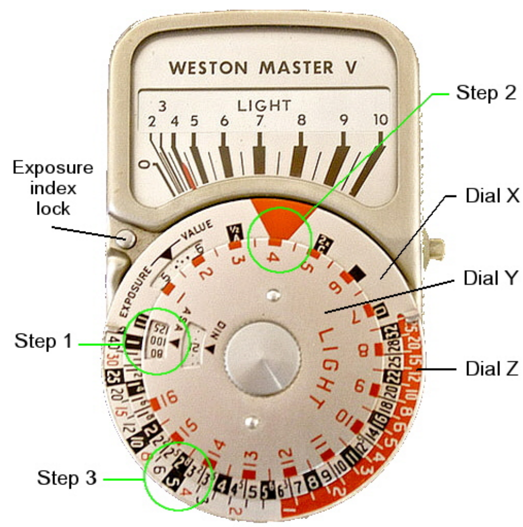

Figure 19. Weston Master V

The exposure calculator comprises three dials. Dial Z is fixed. Dial X is rotated by the user to set into the calculator the meter indication. Dial Y is rotated by the user to set the exposure index, but is stationary during actual operation.

The normal procedure for use is as follows:

Step 1: The position of dial Y is set so that the *exposure index* appears in a small window. The exposure index can be defined as "what we tell the meter is the sensitivity of the film being used". In the different models, this is in terms of different systems.

The mechanics of performing this step varies over the different models. In the model shown, this is done by depressing the exposure index lock button and turning dial X, which will drag dial Y along with it to the desired position. After this step, dial Y mentioned remains fixed. We see here that the exposure index has been set to 100 (in this model, this is in terms of the *ASA speed*).

Step 2: After the meter has regarded the scene and delivered a "reading" of the measured illuminance, the user turns dial X until an arrow on it points to the meter reading on an adjacent scale on the dial Y. The way dial X is moved varies over the different models. On this model, dial X has little tabs to use to move it. We see here that this setting has been to a meter scale ("light") value of "just a little over 4". For our purposes here, we can consider the numbers on the meter scale to be arbitrary.

Step 3: Adjacent rings on dials Y and Z carry, respectively, a set of f-numbers and a set of shutter speeds. Any adjacent pair of f-number and shutter speed will give the photographic exposure "recommended" by the meter, based on the measured scene luminance and the set exposure index. The photographer chooses a pair that best fit the needs of the shot. For example, he may have in mind a certain f-number, to get a certain depth-of-field behavior, or a certain shutter speed, to accommodate a moving subject.

For example, in the figure I call, attention to the almost coincidence of "2^8" (the format used in this model to designate f/2.8) and "5" (meaning a shutter speed of 1/5 second). This means that one "perfect" way to implement the photographic exposure recommendation of the meter is to use a 1/5 second shutter speed and an f-number just a little greater than f/2.8. (Of course, the photographer is probably actually limited to certain discrete shutter speeds and f-numbers, so some compromise may have to be made in doing this.)

B.2 The U-A-(B)-C-O markings

All the exposure meters in described here incorporate a system I describe as the "U-A-(B)-C-O" markings (certainly a peculiar name!).

We begin the story by recalling that, in Step 2 above, the photographer sets the arrow on dial X to the meter reading on dial Y.

Suppose because of some situation (a difficult lighting situation, or the desire for some special artistic effect, the photographer wishes to use a photographic exposure that is greater or less than that the meter would ordinarily recommend, say for example an increase of "one stop" (a doubling of the exposure) or perhaps a decrease of "one stop" (a halving of the exposure).

One way to help the photographer do this would be to provide two alternate arrows on dial X, such that if one is used (instead of the “regular” arrow) to point to the meter reading, the calculator is in effect set to half the meter reading (and the meter would thus give twice then "normal" exposure recommendation), and if the other is used to point to the meter reading, the calculator is in effect set to twice the meter reading (and the meter would thus give half the "normal" exposure recommendation).[6,7]

In the original concept, these three arrows would be labeled "A", "B", and "C". But to make the dial more tidy:

- For the "A" and "C" arrows there is no arrow, just the marking "A" and "C" (with a little more, as we'll see shortly).
- For the "B" (normal) arrow, the marking "B" is omitted. So we have three marks, "A", arrow, "C".

In fact, the "A" mark is also labeled "1/2" and the "C" mark, "2x".

Now because having "A" and "C" marks (but no "B") seems a little strange, Weston concocted a way to explain that. In their manuals, they discuss a common reason to use "exposure compensation". They say that for a scene with low contrast, it is often desirable to reduce the exposure (perhaps by one stop) from that the meter would ordinarily recommend. For a scene with high contrast (perhaps a backlit scene), it is often desirable to increase the exposure (perhaps by one stop) from that the meter would ordinarily recommend.

And the "A" and "C" "alternate arrows" fit into that: "A" can be thought of as meaning "absence of contrast" and "C" as meaning "contrast".

Oh, brother!

Now a further technique of reflected light metering is to take separate readings on different parts of the scene, to be certain that the photometric exposure they will be given by the chosen photographic exposure will lie neatly within the "dynamic range" of the film. This can be done from the camera location is we have a "spot" exposure meter. But it can be done with a meter such as a Weston Master by just going up to the scene and, from a short distance, training the meter separately on the barn door, the horse, the face of the rider, and so forth, noting the meter indication for each.

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[6] As we would expect on a slide rule, the scales on the calculator dials are linear with the logarithm of the quantity represented. Thus a change of 2:1 (or 1:2) in a quantity always corresponds to a the same angular distance on the dial. Thus, if we want an arrow that will cause a 2:1 (of 1:2) change in the calculator's view of the meter reading, we need only offset it from the "normal" arrow by that angular distance.

[7] This is exactly the same concept as "exposure compensation" (technically known as "exposure bias") available in almost all digital cameras with integrated exposure metering systems.

Now, to help the photographer interpret the significance of these "small area" readings, Weston has placed on dial X makers with the letter "U" and "O". These stand for "underexposed" and "overexposed", and they represent the limits of usable photometric exposure for some kind of film.

Then, having set the calculator dials based on an overall scene luminance reading, so that the dials then suggest a certain photographic exposure, we can evaluate the readings from our "local" measurements by seeing where those meter readings, on dial Y, fall within the range between "U" and "O" on dial X. If they all fall within that range, we can be comfortable about the proposed exposure. If not, we may have to adjust the proposed photographic exposure (or, if no "fit" is possible, decide which parts of the scene we will "allow" to be underexposed or overexposed).

B.3 The scale markings and divisions

The basic “division” of the exposure calculator is a difference of “1 stop”, which for meter reading, exposure index, and exposure time is a difference of 2:1, and for f-number is a difference of $\sqrt{2}$:1 (1.414:1).

A secondary division for the exposure index and exposure time, is a difference of “1/3 stop”, which for exposure index and exposure time is $\sqrt[3]{2}$:1 (1.260:1) and for f-number is 1/6 stop, $\sqrt[6]{2}$:1 (1.122:1). For the meter reading, the secondary division is 1/2 stop, $\sqrt{2}$:1 (1.414:1).

When it comes to the labeling of exposure time and aperture, we run into the fact that the theoretical successive values are not all “handy”. Rather, there have been adopted in the photographic industry standard lists of handy “preferred” shutter speeds and apertures (for “1 stop” increments).

The modern-day list has these values (shown compared to the “theoretical” sequence):

	Integral seconds								Fractional seconds (1 over value shown)										
Theoretical	128	64	32	16	8	4	2	1	2	4	8	16	32	64	128	256	512	1024	2048
Preferred	125	60	30	15	8	4	2	1	2	4	8	15	30	60	125	250	500	1000	2000

These at worst only represent very small differences from the “theoretical” series—the worst ones is where the shutter speed “notches” that should theoretically be 1/16, 1/32, and 1/64 second are labeled 1/15, 1/30, and 1.60 second. (The discrepancy there is less than 1/10 stop).

Then, interpolated “handy” values (integral seconds or denominator) are applied to the 1/3-stop notches (starting with 3 seconds and 1/3 second).

A similar situation applies to the f-number scale. The “1-stop” values f/1, f/2, f/4, f/8 etc. are theoretically ideal, The “1/2-stop” values f/1.4, f/2.8, f/5.6, f/11, while not theoretically exact, follow the industry standard of preferred values. The “1/6-stop values are interpolated as handy values (up to one decimal place of the f-number).

B.4 The exposure value (Ev) indication

Under APEX (the Additive System of Photographic exposure), various parameters involved in photographic exposure are given base-2 logarithmic values. The original intent was to allow a photographer to ”work the exposure equation” using only addition and subtraction.

A secondary value of the APEX system is *exposure value*, symbol Ev. This represents, on a base-2 logarithmic basis, the consolidated effect on photographic exposure of a certain exposure time (shutter speed) and aperture (f-number).

The base point of the Ev scale, Ev0, represents the consolidated effect on exposure of an exposure time of 1 second and an aperture of f/1, or any other corresponding combination, such as 2.0 seconds and f/1.4.

Once dial X has been set to the meter indication, the shutter speeds arrayed along dial Z and the apertures arrayed along dial Y, considered in pairs, all represent the same effect on photographic exposure (the one the meter now “recommends”). All these combinations thus have the same *exposure value* (Ev). And in fact that Ev can be read in a little window in dial X (in the figure, seen near the exposure index lock button).

The scale is marked in 1/3-stop increments and can readily be read to 1/6 stop (fractional values of Ev are perfectly valid, though rarely cited).

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Appendix C

Directivity patterns

Figure 20 shows the measured directivity pattern of a Weston Master V exposure meter equipped with a "type 1B" Invercone (in the horizontal plane defined with the meter held vertically . The theoretical cosine pattern is also shown for comparison.

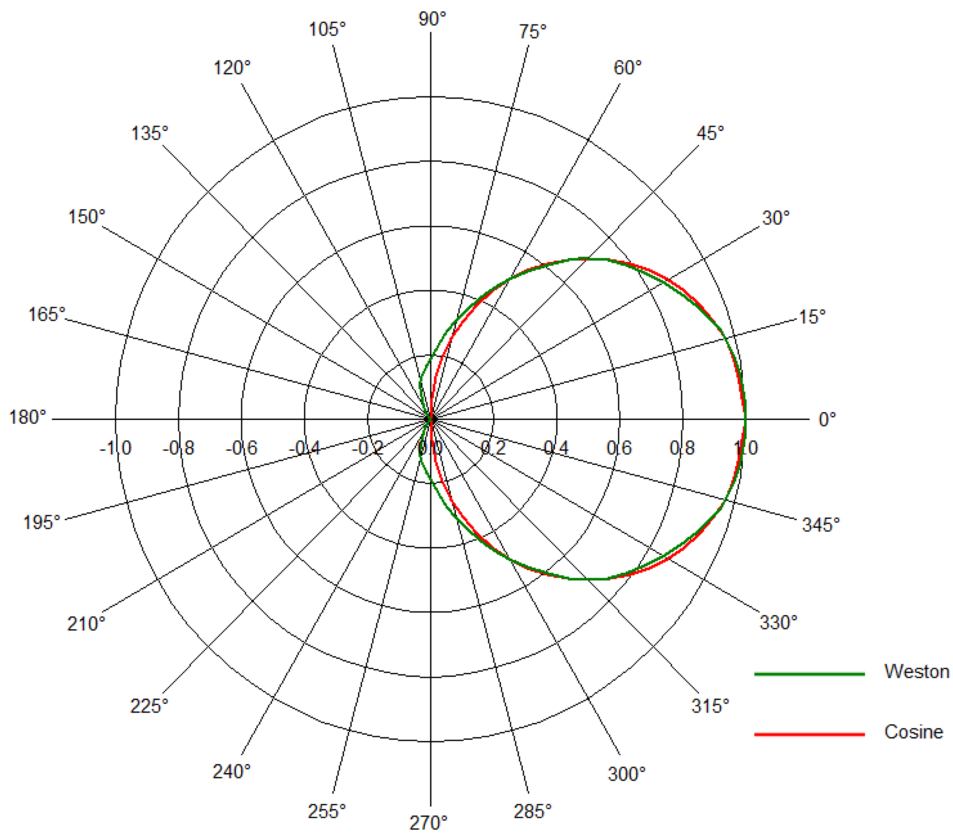

Figure 20. Directivity—Weston Master V with type 1A Invercone

Note that it conforms quite well with the theoretical "cosine" directivity, desirable to measure true illuminance.

Figure 21 shows the directivity patterns of a Weston Master V equipped with a type 2 Invercone.

Here we have two curves, one for the pattern in the vertical plane (that is, vertical with the meter held "vertically") and one for the horizontal plane (same definition).

Note that the horizontal plane directivity pattern, and the upper lobe of the vertical plane directivity pattern, closely follow the theoretical cardioid pattern, as do meters following the "Norwood" concept of incident light metering, using hemispherical incident light diffusers.

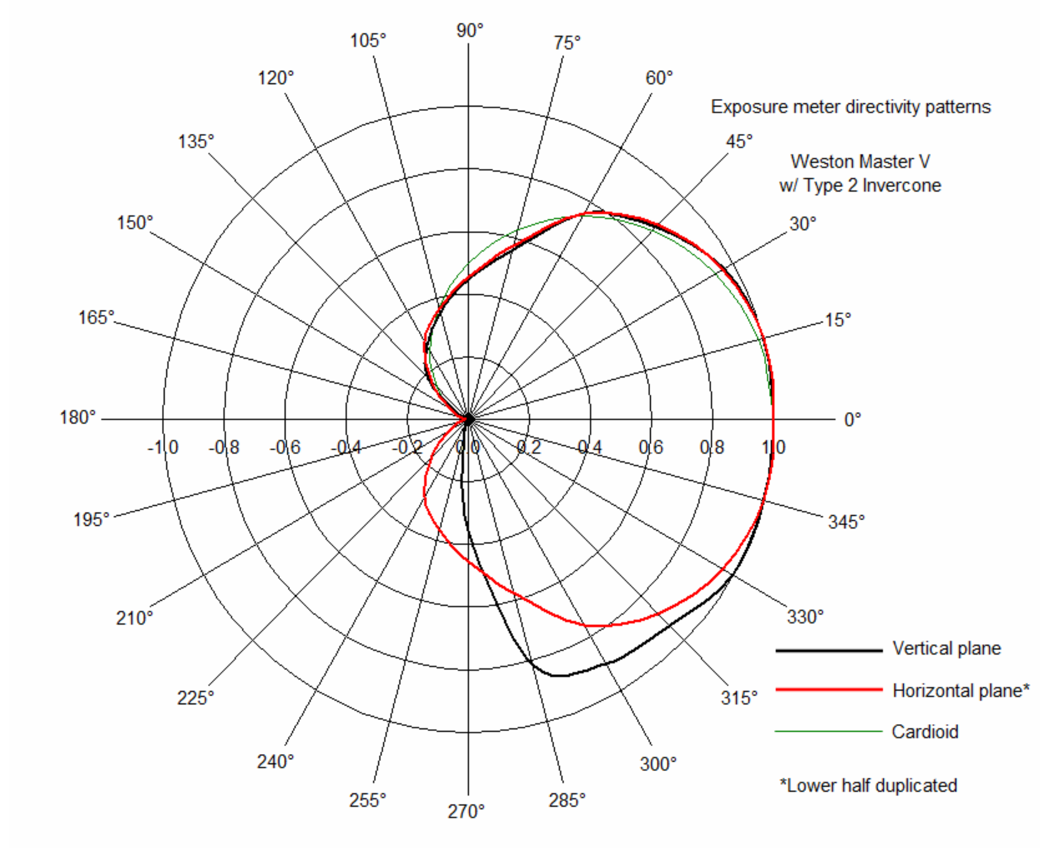

Figure 21. Directivity—Weston Master V with type 2 Invercone

The lower lobe of the vertical plane directivity pattern is somewhat different from the other pattern lobes owing to various phenomena involving the "lower" portion of the meter body.

It is probably in general advisable, when using the Invercone, to hold the meter in a vertical position.

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