OPERATING INSTRUCTIONS

for

TYPE 1501-A LIGHT METER

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

NEW YORK CHICAGO LOS ANGELES

U. S. A.

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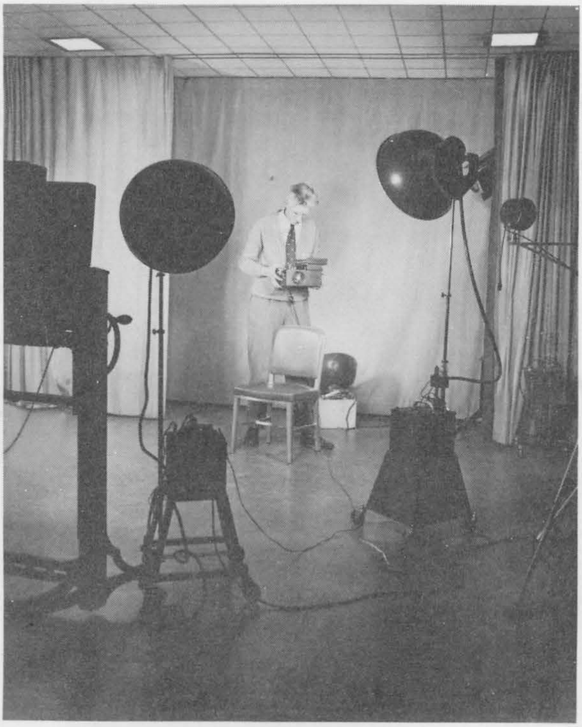

The Light Meter in a Photographic Studio.

SPECIFICATIONS

Light Range: A light range of 64:1 can be measured at mid-scale deflection, corresponding to 100 to 6400 lumen-seconds per square foot (foot-candle-seconds). The extreme readable range is about 50 to 12,800 lumen-seconds per square foot.
Attenuator Range: f/3.5 to f/22 corresponding to a range of 1 to 64 on the proportional scale.
Tubes: One RCA 1P39 and one RCA 1L4.
Batteries: One Burgess 2F, three Burgess XX30E.
Calibration: Meter is standardized at the factory in terms of a calibrated xenon flashtube operated from a known capacitor at a specified voltage. A diffusion disc and aperture is individually fitted to each meter to standardize the reading.

Spectral Characteristics: The phototube has maximum sensitivity in the blue-green portion of the visible spectrum.
Response Speed: For reliable results the flash should be 1/50,000 second (20 microseconds), or more, in duration.
Accessories Supplied: Tubes, batteries, diffusion disc, plug for flash synchronizing circuit.
Other Accessories Available: A probe for light measurements at the camera ground glass is available at extra cost.
Mounting: Walnut cabinet with hinged cover. Base of cabinet carries a tripod socket.
Dimensions: (Width) 7 x (height) 6-1/2 x (length) 11 inches, over-all.
Net Weight: 8-1/2 pounds.

Licensed under designs, patents and patent applications of Edgerton, Germeshausen and Grier.

OPERATING INSTRUCTIONS
for
TYPE 1501-A LIGHT METER

INTRODUCTION - USES

The Type 1501-A Light Meter gives a reading of the total amount of light falling on a phototube through an aperture at the front of the meter. Its primary use is in photography with electric flash tubes of the xenon type (called "Speedlights", "Strob", etc.) to determine the correct camera aperture for color-film exposure.* The General Radio Light Meter differs from ordinary "exposure" meters in that it is designed to sum up and indicate the total amount of light in a short flash, rather than to indicate the average level of continuous illumination.

This meter is also particularly useful in making periodic checks of electric flash tubes used in speedlights to be sure that they have not deteriorated to the point where tube replacement or servicing is desirable. A further use is in comparing the illumination produced by different xenon flash tubes. It is possible to use the meter on other types of flash units and the common combustible flash bulb, if allowance is made for the difference in spectral distribution of the emitted light.

For measuring the intensity of light reaching the film in the camera, an accessory probe (Type 1501-P1) is available which attaches to the back of the camera ground glass with rubber suction cups.

A plate (Type 1501-P2) for mounting a standard Eastman or Wollensack synchronized shutter is also available for testing combustible flash bulbs.

SECTION 1.0 OPERATION

(Note: A description of the electrical circuit and the principles upon which the meter operates will be found in Section 2.0.)

Figure 1 shows two views of the light meter - the panel, and the light aperture, with the controls and adjustments identified.

TO OPERATE THE METER

1. Pull up the ON switch. The neon pilot light will glow, and the meter will swing down scale, then return to near zero.

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*Harold E. Edgerton, "Photographic Use of Electrical Discharge Flashtubes," Journal of the Optical Society of America, July 1946, Vol. 36, No. 7.
Harold E. Edgerton, "Light Meter Uses with Electronic Flash," P.S.A. Journal, Part II, January 1950, p 6.

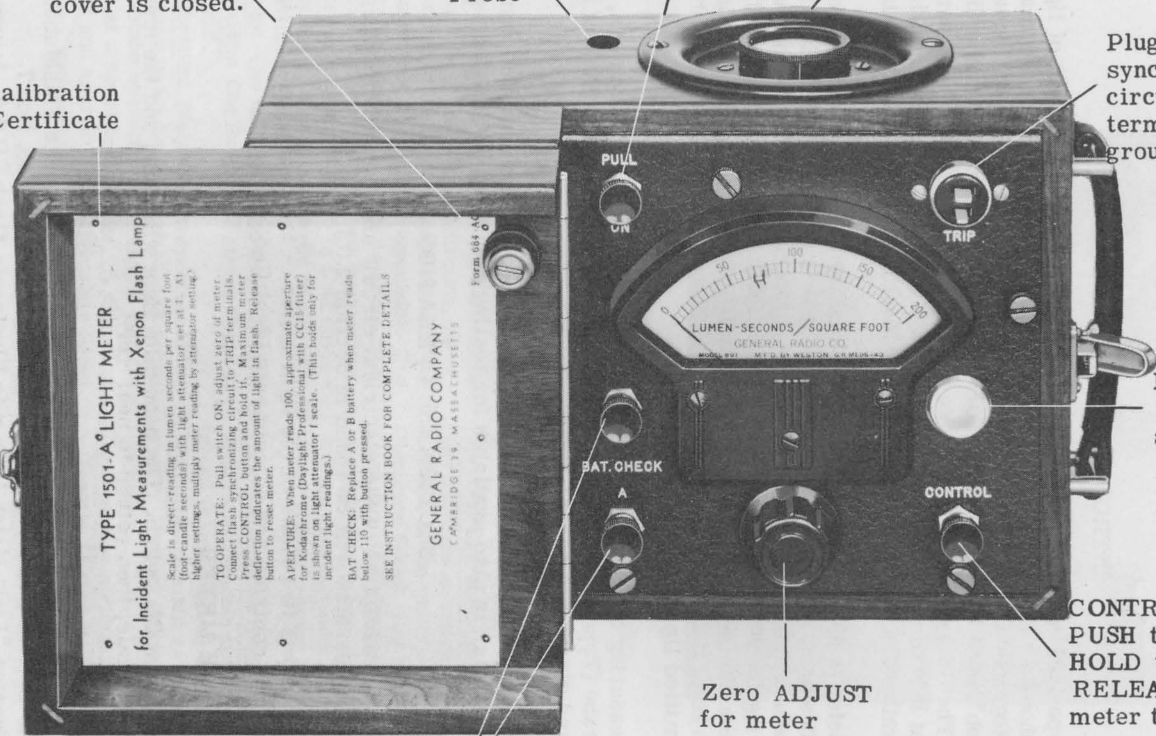


Figure 1a. General view of Type 1501-A Light Meter.

2. Set meter to zero with ZERO ADJUST knob. The zero may drift slightly and should be checked periodically.

3. Connect the external flash synchronizing circuit to the plug on the panel. A mating plug is provided for making these connections. The large terminal should be the ground connection.

4. Place meter at the subject position so that light from flash is directed toward the meter aperture.

Tripod mounting thread (1/4-20) is provided on bottom of meter.

5. Press CONTROL button and <u>hold it way down.</u> Meter will deflect up scale, and the indication is a measure of the amount of light in the flash. Meter is reset to zero by releasing the button.

6. Check batteries occasionally. (See Section 3.0.)

TO DETERMINE CAMERA APERTURE - INCIDENT LIGHT METHOD

Mounted in front of the aperture are two polaroid disks, one of which can be rotated with respect to the other. These act as a light attenuator, so that the amount of light admitted through the meter aperture can be adjusted.

Figure 1b. Close-up of Polaroid Light Attenuator

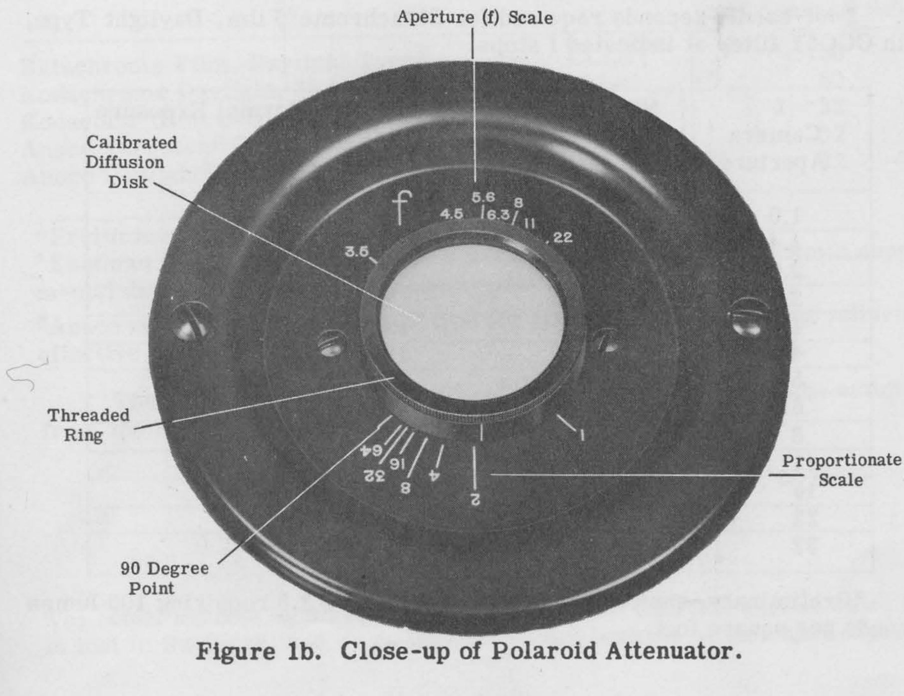


Figure 1b. Close-up of Polaroid Attenuator.

Supplied with the meter is a diffusion disk, which mounts over the polaroid attenuator. THIS DISK MUST BE IN PLACE WHEN THE METER IS USED TO DETERMINE CAMERA APERTURES FOR COLOR PHOTOGRAPHY. This diffusion disk makes the meter scale direct reading in lumen-seconds per square foot (foot-candle seconds) when the attenuator ratio (proportionate scale) is set at "1". At other values such as 8, the lumen seconds per square foot or foot candle seconds are obtained by multiplying the meter reading by the factor 8.

The following directions are for use of electric flash lamps (xenon) and Ektachrome Film, Daylight Type, which requires about 100 foot candle seconds at f/3.5 for average subjects with direct front lighting, and corresponding greater illumination at smaller apertures (see Table I).

1. Place meter at position of subject to be photographed, with meter aperture toward the flash lamp.

2. Set polaroid attenuator to some convenient f value, say f/11.

3. Press control button to end of stroke.

4. Note meter reading. This reading is in lumen-seconds per square foot when multiplied by the proportionality factor (about 10 for f/11).

TABLE I*

Foot-candle seconds required for Ektachrome Film, Daylight Type, with CCO5Y filter at indicated f stops.

f Camera Aperture	Meter Reading at Subject for Normal Exposure Foot Candle Seconds (Lumen-Seconds/sq. ft.)
1.0	8.13
1.4	16
2.0	32.5
2.8	64
4.0	130
4.5	165
5.6	256
6.3	326
8	520
11	986
16	2080
22	3940
32	8380

*Preliminary, subject to revision, based on f/3.5 requiring 100 lumen seconds per square foot.

5. If meter reading is 100, f/11 is the correct aperture for normal subjects with Ektachrome Film, Daylight Type. (See Table II for other color materials.)

6. If meter reading is below 100, camera aperture for normal subjects must be larger (lower f number) as indicated in Table I. If reading is above 100, camera aperture must be small (higher f number).

7. Correct aperture for any arrangement of lights can also be determined directly by changing the attenuator setting and repeating measurements until meter reads 100. Correct aperture is then read directly from scale on the polaroid attenuator.

8. If some particular camera aperture is to be used in taking the photograph, the meter attenuator should be set to this aperture, and the lights readjusted until the meter reads 100.

A table of meter readings for average exposure for some of the commonly used color emulsions is given in Table II for f/3.5 aperture.

TABLE II*

Film	Suggested Filter For Xenon Flash	Required Meter Reading (foot candle seconds) at f/3.5; Incident Exposure and Average Subject
Ektachrome Film, Daylight Type+	CC05Y	100
Kodachrome Daylight, 35 mm and Bantam	81-C	60
Kodacolor (Roll only)	81-C	32
Ansco Tungsten# Color Positive	Conv. 11	32
Ansco Daylight# Color Positive	UV-16	32

*Preliminary, subject to revision.

+Eastman Kodak supplies with each box of Ektachrome Street Film a supplemental data sheet with filter recommendations.

#Ansco recommends the Daylight type for xenon flash. Processing influences effective speed.

The above values of incident light for any type of film can be estimated from the Exposure Index S as follows:

$$I = \frac{CA^2}{TS} \text{ foot candles (A.S.A. Standard Z 38.2, 6. 1948)}$$

or $$IT = CA^2/S \text{ foot candle seconds}$$

The actual incident light required is usually larger than this amount since light is lost in the filter, and extra light is needed because of the short exposure.

The use of the light meter for color photography has been described in terms of the simplest type of lighting where the lamps are grouped at or near the camera. This type of lighting is seldom used and therefore the photographer must adapt the meter to his particular type of lighting.

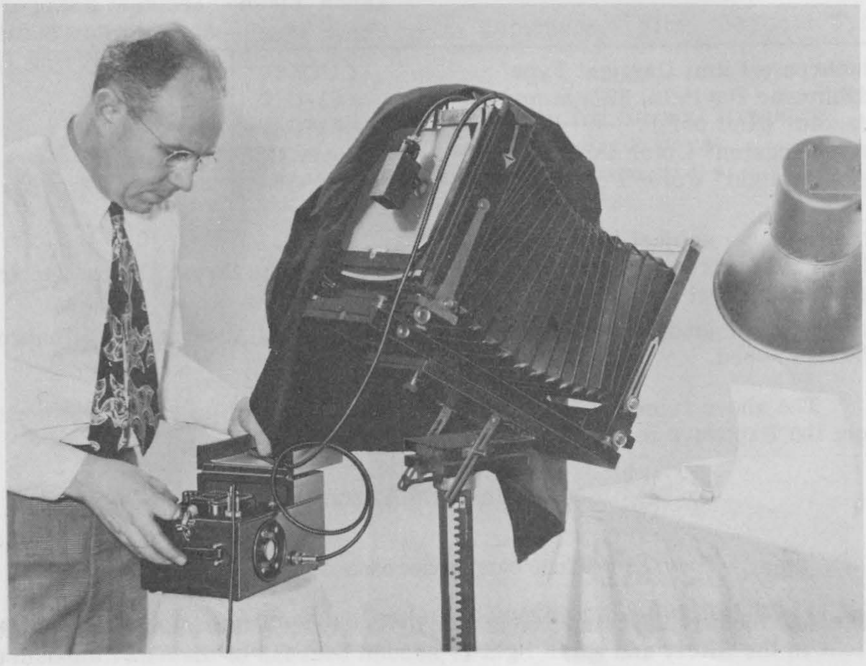
One system is to measure the incident light at the subject from each source separately in a direction perpendicular to the source. Experience will indicate the ratio between different sources for main and fill lamps. Many photographers use a figure of 2 to 4 between the main key light and the fill-in lamps.

The standard bellows extension corrections should be applied for any particular setup.

USE OF PROBE TO MEASURE LIGHT AT FILM SURFACE

Plug probe cord into meter case as indicated in Figure 2. Place a large white card on the subject to be photographed, and focus camera to produce

Figure 2. Light meter with probe arranged to measure light at camera groundglass. The probe is covered with the dark cloth when the actual tests are made to exclude leakage light.



sharp image of card on ground glass. Next, attach probe to ground glass over image of white card, and cover back of camera and probe with black cloth to exclude all external light. Open the lens and press control button to operate flash and note meter reading. The stray light entering the probe from the back can be measured by covering the front of the camera lens so that no light falls on the ground glass from the front.

Be sure that the image of the white card is at least as large as the light-acceptance hole in the probe.

If the meter reading is too high, a Kodak Neutral Test Card with 18% reflectance can be used as a standard test surface.

There is considerable variation in ground glass material on different cameras; therefore, separate light meter readings should be taken on each camera.

The loss of light due to bellows extension is taken into account when using the light meter probe at the film plane. Therefore, the conventional bellows extension corrections are not required.

When using the probe always set the light attenuator to the 90° point (see Figure 1), or cover the aperture so that light will not enter the usual opening on the meter. A solid disk is furnished with the probe for this purpose.

No means of standardizing has been provided for readings taken with the probe. The user can determine the significance of the meter indications by making a few trial exposures. Since individual Type 1P39 phototubes may differ in sensitivity by as much as 3 to 1, two light meters, <u>when used with the probes,</u> will not necessarily give the same reading.

The measurement of light energy received at the ground glass in the most fundamental way to measure exposure since all factors such as aperture, lens absorption, bellows extension, etc., are included. Eventually, tables of exposure for all film materials will be available.

For other uses of light meter, see Section 4.0.

SECTION 2.0 CIRCUIT AND PRINCIPLES OF OPERATION

The electrical circuit is shown in Figure 3. Light entering the aperture on the front of the meter, after being attenuated by a pair of calibrated rotatable polaroid disks, strikes the phototube and produces an electric current proportional to the light intensity. This current is integrated, or summed up, in a capacitor, and the voltage across the capacitor is proportional to the exposure, or quantity of light received by the phototube. A vacuum-tube voltmeter indicates this capacitor voltage.

The CONTROL pushbutton performs three operations in sequence as the button is pushed: (1) the light-integrating circuit is made active; (2) the external synchronizing circuit connected to the plug on the panel is closed to actuate the electric flashbulb; (3) the phototube circuit is opened so that any continuous light impinging on the photocell will not unduly affect the meter reading, and the meter reading is held for a reasonable time if the button is held down. Circuit is reset on release of the button. A rapid push is required if the ambient light is high. A test with flash disconnected will indicate the error due to ordinary light.

Hold pushbutton in mid-position for open flash operation.

ATTENUATOR

The attenuator consists of two polaroid disks, one of which can be rotated. Any degree of light transmission from complete transmission to almost complete extinction can be obtained. One scale is used for camera aperture settings; the other for direct measurements of illumination. Maximum extinction occurs when the indicator is set at the short un-numbered line shown as the 90° point in Figure 1.

CALIBRATION

To obtain incident light per unit area received at the front of the light meter,

U = kRW foot candle seconds (lumen-seconds per square foot) (calibrated with a standard xenon flashtube)

where W = meter reading

R = multiplying factor as set on the proportionate scale on the polaroid attenuator on the front of the meter (not f numbers). The accuracy decreases for large ratios since the angle between steps is smaller. A 20% error may be experienced for the 64 range, while lower ranges are accurate to about 5%.

k = a constant for the meter as calibrated with the output of a standard FT-214 (General Electric Company) flashtube. A calibrated diffusion disk is furnished which makes k = 1 so the meter is direct reading.

TIME OF FLASH

The light meter will indicate a low value of total light if the flash duration is less than about 1/50,000 second for a full-scale deflection. For readings of less than full scale, the allowable flash duration is proportionally shorter.*

*Harold E. Edgerton, "Photographic Use of Electrical Discharge Flashtubes." Journal of the Optical Society of America, July 1946, Vol. 36, No. 7.
Harold E. Edgerton, "Light Meter Uses with Electronic Flash," P.S.A. Journal, Part II, January 1950, p 6.

FILTERS

Neutral density filters can be used to extend the scale range. Thus a 1/10 transmission filter would give a multiplying factor of 10. Neutral density filters are available from the Eastman Kodak Company and other suppliers in decimal, logarithmic, or percentage steps. The threaded ring accepts series V filters (1-3/16 inch diameter).

Recalibration for any other filter disk can be accomplished by experimentally determining k by the ratio of two readings - one with and one without the new filter that is to be used.

ANGLE OF LIGHT ACCEPTANCE

The meter reading decreases 50% when the instrument is turned about 15 or 20 degrees from the lamp-subject line without the diffusion disk. The diffusion disk, which gives a k = 1 factor, increases the above angle to about 25 degrees.

OTHER PHOTOTUBES

The light-meter calibration is made with a specific phototube (Type 1P39) which is a vacuum-type tube with an S-4 surface. Thus, if the phototube is exchanged for other phototubes, the calibration will not hold. The S-4 surface has a peak sensitivity in the blue portion of the spectrum at 4100 A. The sensitivity decreases from this peak to the cut-off value which is in the orange. Very little red light is measured. See curves, Figure 4.

OTHER FLASHTUBES

The phototube in the light meter will respond to the light from any kind of light source. However, the meter output cannot be expressed in lumen-

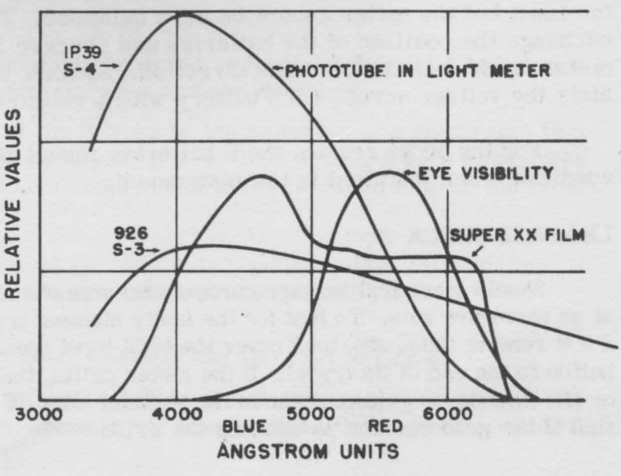


Figure 4. Spectral Sensitivity Curves.

seconds per square foot unless the spectral distribution is the <u>same as the xenon flashtube</u> that is used for calibration. All xenon flashtubes, to a first approximation, have a comparable spectral distribution and therefore the meter readings can be given in terms of lumen-seconds even if the phototube spectral sensitivity does not match that of the standard eye.

SECTION 3.0 ROUTINE MAINTENANCE

BATTERY CHECK

If the meter reads less than about 110 when either of the BATtery CHECK buttons is pushed, that battery needs to be replaced, although the meter may operate even if the battery reads as low as 90. New batteries should give several hundred hours of continuous use. However, even without use, the batteries should be changed twice a year because of battery deterioration.

Do not leave the batteries in an instrument that is stored as the batteries may swell and leak after their expiration date is exceeded.

New batteries will read approximately as follows when BATtery CHECK button is depressed.

A battery - 1.5-volt, 2F Burgess or equivalent - 145 on meter
B battery - 45-volt, XX30E Burgess or equivalent (3 required)
135 on meter.

The battery compartment is opened by removing the four screws on the top of the hinged cover.

The B batteries should run down at the same time since they all draw the same current. However, should one battery become discharged much earlier than the other two, it is possible that the B battery reading will not be below the limit but the meter cannot be zero balanced. To find if this is the case, exchange the position of the batteries and observe if the zero position of the meter is off scale in the same direction. Another test is to measure separately the voltage across each battery with a voltmeter.

For the above reason, the B batteries should all be of the same date and condition when installed in the instrument.

LEAKAGE CHECK

Should electrical leakage currents become excessive, the meter will drift at an excessive rate. To test for the faulty element try the following procedure. First remove the probe, then cover the light input opening and depress the push-button to the end of its travel. If the meter drifts, the leakage is either wiring, or the switch, or grid current in the vacuum tube. Change the vacuum tube to find if the grid current is causing the drift.

If the drift occurs when the pushbutton is in the half-way position, then the leakage is due to the phototube or its circuit. Change the phototube.

If excessive drift cannot be eliminated the instrument should be returned to the Service Department at the factory.

TUBES

Phototube Type RCA 1P39

Amplifier tube, Type 1L4, must be selected after aging for low grid current, or the meter will drift when button is pushed.

Suitable 1L4 tubes are available from the General Radio Company. The calibration will not be appreciably influenced by a replacement amplifier tube, but must be checked when phototube is replaced.

STANDARDIZATION

Where the light meter is to be used in standardizing measurements, it is recommended that a standard flashtube be used for periodic calibration checks. Any xenon flashtube operated from a known capacitor at a specified voltage can be used as a standard flashtube if the duration of flash is greater than 100 microseconds. The standard flashtube used at General Radio is a General Electric FT-214 tube flashed from 100 microfarads charged to 2000 volts. With 200 watt seconds, as described, the average FT-214 will have an output of 625 horizontal-candle-power seconds (HCPS). The front of the light meter should be located 30 inches from the center of the flashtube to obtain a 100 foot-candle-second incident-light meter reading.

Care must be used with a test of the above type to eliminate reflected light from objects near the standard flash bulb. Such light can easily introduce 20 percent error in the incident light received by the meter. The use of light shields and black velvet material over objects in close view is recommended.

DIFFUSION DISK

The diffusion disk should be inspected at frequent intervals to be sure that it is clean and has not deteriorated or been damaged.

The meter is adjusted at the factory by the selection of a diaphragm that permits calibration to be made by adjusting R-2. This disk is always assembled inside the diffusion disk, and both disks mount in the threaded ring on the front of the attenuator mounting.

SECTION 4.0 OTHER USES OF LIGHT METER

USE OF LIGHT METER TO TEST CONDITION OF FLASHTUBES

The meter, when the calibrated diffusion disk is in place, reads directly in foot-candle-seconds (lumen-seconds per square foot). Consequently, routine measurements at any convenient, fixed test distance from lamp to meter will measure the horizontal light output of the lamp directly. For direct measurements in lumen-seconds per square foot, the attenuator index should be set at 1 on the proportionate scale. Other settings indicate multiplying factors for the meter scale.

MEASUREMENT OF THE OUTPUT OF A SOURCE AT A DISTANCE

The output in beam candlepower seconds of a source can be calculated from the meter reading, the attenuator setting, and the distance between source and meter:

$$\text{Beam CPS} = kWRD^2$$

where $k = 1$, when diffusion disk is in place, W = meter reading, R = attenuator setting (proportional scale), and D = distance in feet between lamp and meter.

MEASUREMENT OF THE TOTAL OUTPUT OF A BARE LAMP WITHOUT A REFLECTOR

If the light output is constant in all directions, the total output in lumen seconds is obtained by multiplying the candle-power seconds by 4π. For most tubes this factor is about 10 instead of 4π since the base of the lamp absorbs some of the output and because the lamp is non-symmeterical.

Total output in lumen seconds, Q, = CPS x 10 = meter reading x attenuator x D^2 x 10 (approximately, for average lamp).

$$Q = kWRD^2 \times 10$$

A more accurate method is the use of a large integrating sphere for comparing the total light with the total light from a standard flashtube.

COMBUSTIBLE FLASH BULBS

The TRIP terminals can be used to fire the ordinary combustible flash bulb if a battery is wired in series with the TRIP terminals and the bulb. A fairly slow push on the button will enable a reading to be made of the entire light output. If the pushbutton is pushed too fast, the circuit of the photo electric tube might be opened before the combustible flash bulb has gone out and thus, the meter will not integrate the entire output. The amount of light from usual lighting sources does not influence the reading even for a fairly long push. However, it is easy to measure the error for any case simply by reading the meter with the type of push that is to be used for the flash measurement.

The meter is <u>not calibrated</u> for the light from combustible flash bulbs since the color temperature is different than that of the xenon flashtube, but comparison readings can be made between flash bulbs of the same type.

ACCESSORY SHUTTER WITH TRIP CONTACTS

A plate (Type 1501-P2) mounting a standard Eastman, Wollensack, or other synchronized shutter can be supplied, at extra cost, for testing combustible flash bulbs. The shutter contacts are arranged to give the conventional 5 or 20 millisecond lead time before the shutter leaves open. Also the shutter open time can be adjusted over a considerable range of time corresponding to values used in photography.

Comparison of the "open flash" light from a combustible flash bulb can in this way be made with light from "synchronized" shutter combinations.

It must be remembered that the pushbutton must be in the mid-position of the push when the shutter operates, otherwise a reading will not be made. Some care is required to hold the pushbutton at the right point. Usually the meter reading will drift slowly when the switch is right; a coin such as a penny can be used as a shim under the pushbutton edge.

MEASURING THE OUTPUT OF A FLASH UNIT

The output from a flash unit can be expressed in beam-candle-power-seconds, usually abbreviated as BCPS. To make this measurement,:

1. Place the meter at a measured distance, D, from the center of the flash bulb. This distance should be at least 10 times the reflector diameter.

2. Connect a synchronizer cable from the light meter trip plug to the flash unit circuit.

3. After turning on the meter, first adjust the zero, and then set the front Polaroid attenuator to 1. (F = proportionality factor)

4. Now point the front of the meter towards the flash reflector on the main axis and push the "operate" button. Hold this switch down until the meter reading, W, has been taken.

The meter reads the incident light, WF, in Lumen seconds per square foot. To obtain candle power, multiply the meter reading, W, by distance squared, D^2, and the Polaroid attenuator factor, F. Thus,

$$BCPS = FWD^2 \text{ beam-candle-power-seconds}$$

where FW = Lumens-per-square-foot (meter reading W times attenuator factor, F)

D = Lamp to meter distance in feet.

Now assume the reflector to be removed from the flash tube so that the light from the bare tube can be measured. This is measured with the meter exactly as has been described above. The meter reading will be lower in value since the reflected light is not present.

$$HCPS = FWD^2 = \text{Horizontal candle-power-seconds output of bare flash tube.}$$

REFLECTOR FACTOR

The ratio of the BCPS to the HCPS of the same flash lamp without the reflector is an important quantity which we can call the "Reflector Factor, M".

$$M = \frac{BCPS}{HCPS} = \text{Reflector Factor}$$

REFLECTOR BEAM SPREAD

The next item of interest is the beam spread of the reflector. This can be measured with the light meter by changing the angle and then reading the light as above. In general, the light will be the largest at the center and will drop off as the reflector is swung from the central beam. An actual curve of this variation with the angle can be measured and plotted. Often it is convenient to measure the total angle between the rays of light that are each 1/2 of the maximum beam-candle-power at the center of the reflector axis.

Often a highly specular reflector will measure a large reflector factor, M, but will give a narrow bright spot or image of the flash tube. In this spot the light may be very large. However, such a reflector is not satisfactory for most photography, since the subject will not be illuminated evenly. The light meter enables the reflector designer or the user to find out what each reflector does as far as light distribution is concerned.

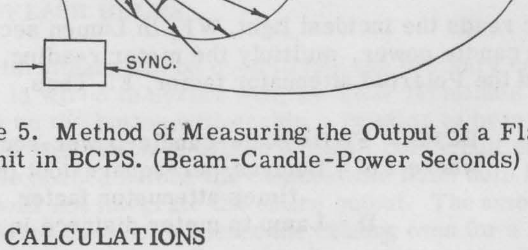


Figure 5. Method of Measuring the Output of a Flash Unit in BCPS. (Beam-Candle-Power Seconds)

GUIDE FACTOR CALCULATIONS

The approximate guide factor for a flash unit can be calculated from the following equation:

$$DA = \sqrt{\frac{S}{C} BCPS} \quad \text{or} \quad \sqrt{\frac{S}{C}\frac{Q}{4\pi}M} \qquad BCPS = \frac{Q}{4\pi}M$$

where D = Lamp to subject distance in feet
A = Camera aperture of f/-number
S = ASA film exposure index (see A.S.A. 238.2.1 - 1947)
C = A constant between 15 and 30 (see A.S.A. Z 38.2.6 - 1948)
BCPS = Beam-Candle-Power-Seconds
Q = Total lumen output of flash tube
M = Reflector factor

Example: What is the Guide Factor of a flash unit that is to be used with a film having an ASA exposure index of 200: The BCPS output is 2000. The guide factor, DA, is then

$$DA = \sqrt{\frac{200}{15}\ 2000} = 163$$

(or with C = 30, DA = 133)

These values show the range of numbers that might be involved. Considerable variation can be obtained by development. With fresh film, fresh developer, agitation during development, increased development time, and so forth, the guide factor can be materially increased, especially if a thin negative is acceptable. If a dense well-exposed negative is required, then the guide factor should be selected on the low side of the above.

Example: Suppose a photograph (at f/11) of a football game is desired where the flash lamps are 200 feet from the subject. Calculate the required watt seconds of energy in the flash unit.

Assume ASA film exposure index S = 250

C = 15
M = 10 reflector factor

$$\text{then} \quad D = \sqrt{\frac{S}{C}\,\frac{Q}{4\pi}\,M}$$

$$\text{or} \quad Q = \frac{D^2 A^2\, 4\pi C}{SM}$$

$$= \frac{200^2\ 11^2\ 4\pi\ 15}{250 \quad 10}$$

= 365,000 lumen seconds.

Assume n = 36.5 lumens/watt

$$\text{then} \quad \frac{CE^2}{2} = \frac{365{,}000}{36.5} = 10{,}000 \text{ watt seconds.}$$

This is a rather large size of flash unit. If 3000 watt seconds were used, the aperture would need to be changed from f/11 to f/11 x $\sqrt{\frac{3000}{10{,}000}}$ = f/6.

From a practical standpoint, an aperture of f/11 with 3000 watt seconds probably would be satisfactory if the uniforms of the players are light in color as they usually are and if a thin negative is acceptable. One should remember, however, that there will be no reflections as are found indoors to help the exposure.

It should be emphasized that actual photographic tests should be made to check the calculations above. Each photographer can then find a value for the constant C that will give him the type of negative that he desires.

EFFICACY OF A FLASH TUBE

The output of a flash tube can be measured in Horizontal-Candle-Power-Seconds (HCPS) as follows:

1. Direct the photocell opening towards the flash tube at the side whose horizontal-candle-power-second output is desired.

2. Adjust the Polaroid attenuator to 1 and turn on the meter. Also connect a synchronizing cable between the meter and the flash lamp triggering circuit.

3. Push down on the "operate" button and hold it down until the meter is read. The incident light is FW lumen seconds/square foot where F is the attenuator ratio (X 1 etc.) and W is the meter reading.

The output is then

$$FWD^2 = HCPS$$

The electrical input to the flash tube is

$$\frac{CE^2}{2} \text{ watt seconds}$$

where C = capacitance in farads
E = initial voltage to which the capacitor is charged.

The efficacy, N, is then

$$N = \frac{HCPS}{\frac{CE^2}{2}} = \text{horizontal-candle-power per watt}$$

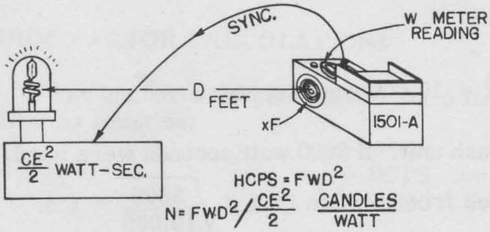


Figure 6.
Schematic Diagram Showing the Factors Involved in the Determination of the HCPS

The total lumen second output is

$$Q = 4\pi \text{ HCPS lumen seconds}$$

if the flash lamp is a sphere. For practical sources, the factor 4π is closer to 10. The efficacy in lumens per watt is

$$N = \frac{Q}{\frac{CE^2}{2}} = \frac{10HCPS}{\frac{CE^2}{2}} = \frac{\text{lumens}}{\text{watt}}$$

assuming 10 to be the factor between horizontal-candle-power and lumens.

GUIDE FACTOR WITH COLOR FILM

Example: Find the color guide factor of a flash unit which has an output of 2000 BCPS when used with 35 mm Kodachrome film daylight type.

From Table I, the required incident light at the subject is 20 lumen-seconds per square foot at f/3.5.

Calculate the distance as follows:

$$D^2 = \frac{2000}{20}$$

$$D = \frac{2000}{20} = 10.$$

And the guide factor DA = 10 x 3.5 = 35.

The guide factor can also be calculated from the equation.

$$DA = \frac{S}{C} \text{ BCPS} = \frac{10}{15} 2000 = 36.5$$

$$\text{or with } C = 25, DA = 28.2$$

A filter that reduces the blue light by about 30% is used by many photographers. However, some people are entirely satisfied with the unfiltered pictures. The guide factor might be slightly larger for the unfiltered use.

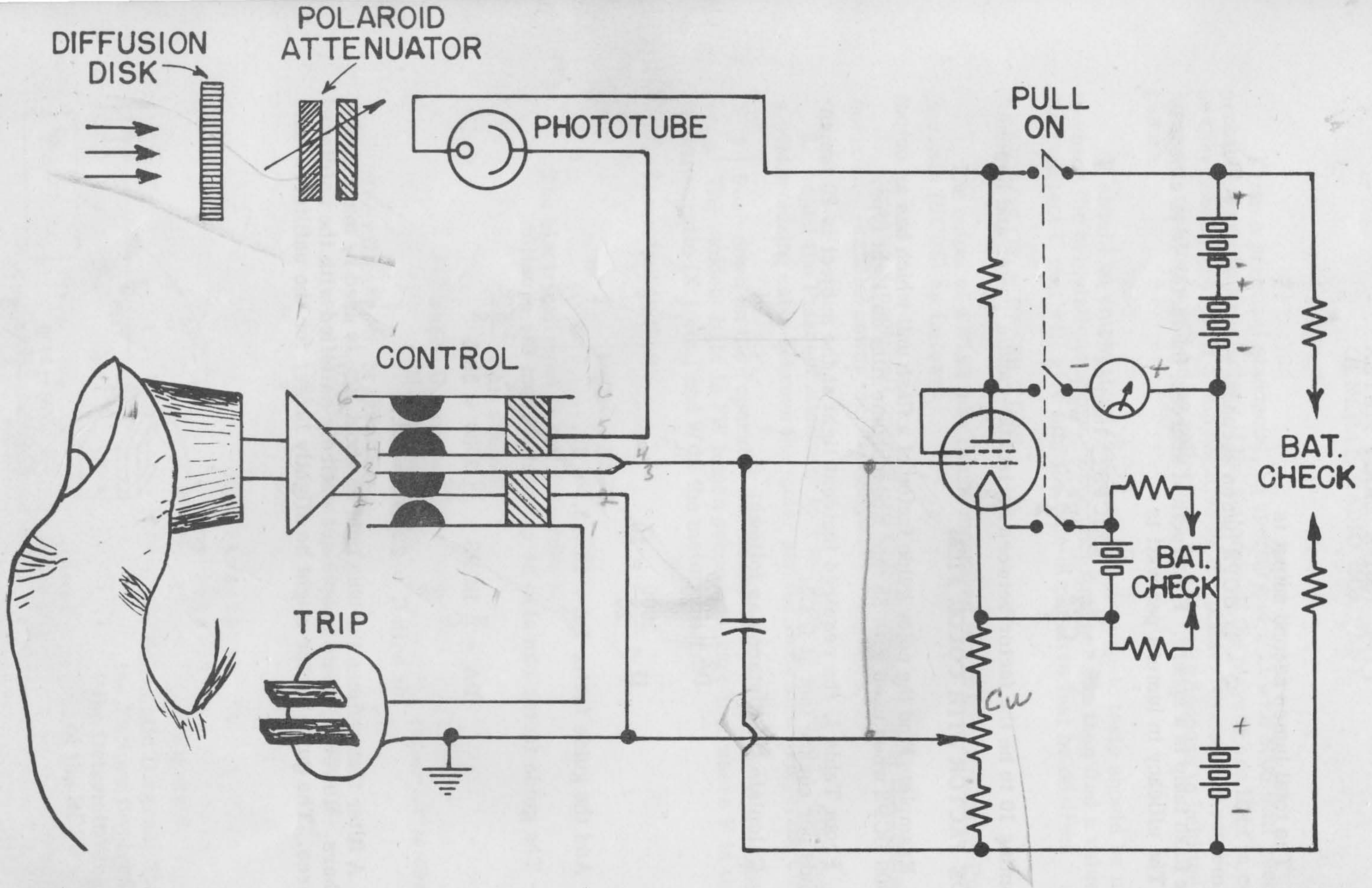


Figure 3a. Schematic Circuit Diagram of the Type 1501-A Light Meter.

RESISTORS

R1	=	3.3 K Ohms		POSW-1
R2	=	26 K Ohms		POSC-11
R3	=	220 K Ohms	±10%	REC-21BF
R4	=	2.2 K Ohms	±10%	REC-21BF
R5	=	2.7 K Ohms	±10%	REC-21BF
R6	=	470 K Ohms	±10%	REC-21BF
R7	=	4.7 K Ohms	±10%	REC-21BF
R8	=	510 K Ohms	± 5%	REC-21BF
R9	=	5.1 K Ohms	± 5%	REC-21BF
R10	=	1 Megohm	±10%	REC-21BF

CONDENSERS

C1	=	0.05 μf	±10%	COP-9-2

MISCELLANEOUS

M1	=	Meter	MEDS-43
SO-1	=	Socket	CDMS-15-2
S1	=	Switch	SWP-14
S2	=	Switch	SWP-12
S3	=	Switch	SWP-13
S4	=	Switch	SWP-13
PL1	=	Plug	CDMP-14-2
PL2	=	Plug	CDMP-1424
PL3	=	Plug	CDMP-1424
PL4	=	Plug	CDMP-1424
PL5	=	Plug	CDMP-1425

Battery 45v. Burgess.#XX30E
Battery 1.5v. Burgess.#2F

TUBES

V-1	=	1P39
V-2	=	1L4
V-3	=	NE-51

SEQUENCE OF SWITCH OPERATION ON:

S-1 Normal position 1-2 open, 2/3 closed, 4-5 closed. As plunger is pressed, 2 & 3 must open before 1 & 2 closesand 1 & 2 must close before 4 & 5 opens, bend #6 so #5 does not touch in maximum position.

S-2 When plunger is pressed to open switch, contacts 1 & 2 must open first to break "A" battery connection ahead of "B" battery connections.

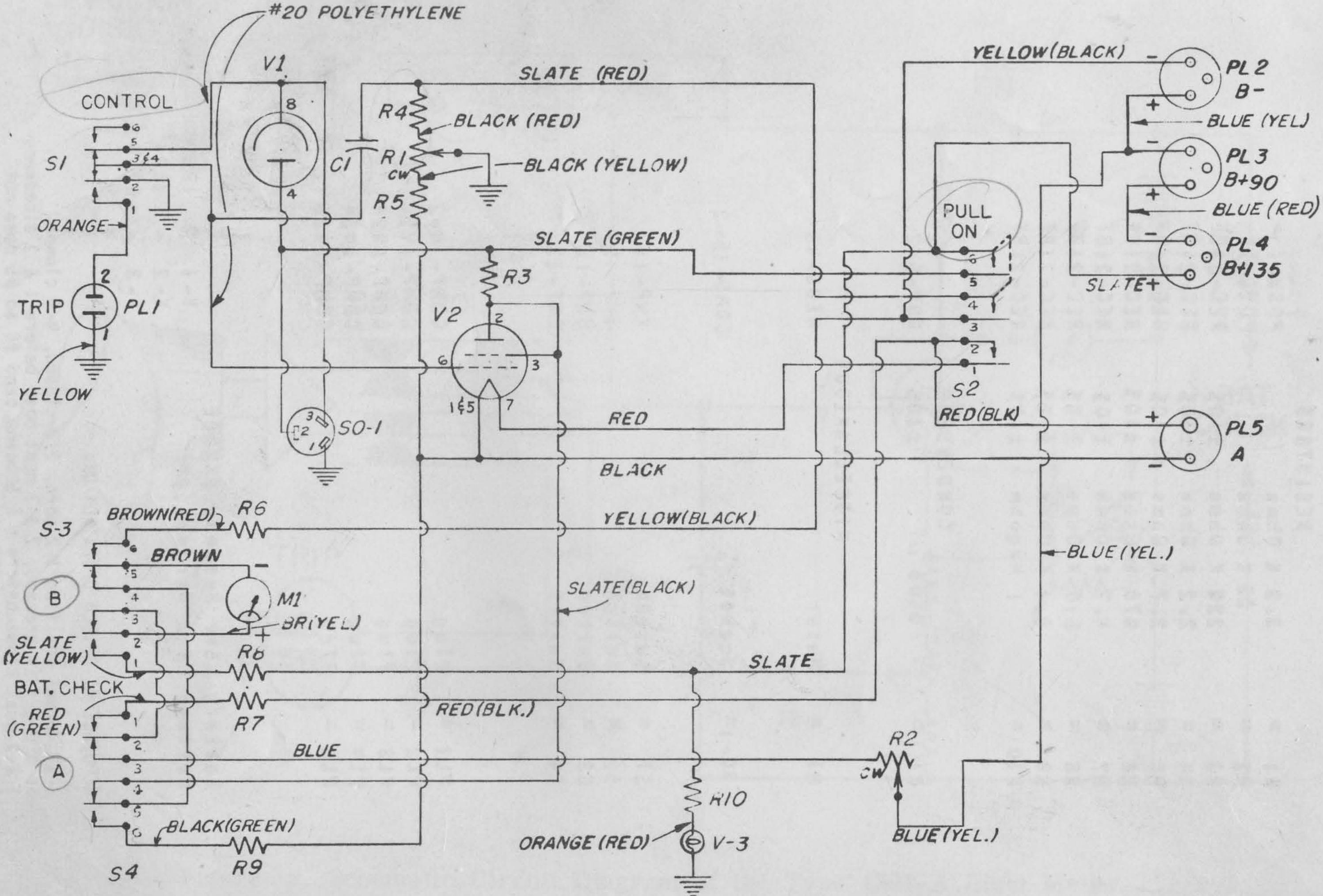


Figure 3b. Complete Wiring Diagram of the Light Meter.