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MILITARY STANDARD

STATIC ACCEPTANCE TESTS FOR LIGHT OUTPUT OF FLASH MUNITIONS

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
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Supply and Logistics

Static Acceptance Test For Light
Output of Flash Munitions

MIL-STD-277

1. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force, effective 1 March 1956.

2. In accordance with established procedure, the Standardization Division has designated the Ordnance Corps, Bureau of Ordnance, and Air Force, respectively, as Army-Navy-Air Force custodians of this standard.

3. Recommended corrections, additions, or deletions should be addressed to the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics), Washington 25, D. C.

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FIGURES

1. SCOPE

1.1 Scope. These tests are used to determine acceptability of a lot of flash items by static testing and by measurement of the light output of a representative sample. The tests are applicable to all types of flash munitions.

2. REFERENCED DOCUMENTS

2.1 The following drawings, of the issue in effect on date of invitation for bids, form a part of this standard:

ORDNANCE CORPS DRAWINGS

P–72142—Housing, Photocell, Counter-Type Integrator Assembly

P—72143—Housing, Photocell, Counter-Type Integrator Details

P—72144—Housing, Photocell, Counter-Type Integrator Details

(Copies of drawings required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 Lot. In general, a lot shall consist of items produced by one manufacturer in one unchanged process, in accordance with the same drawing, same drawing revision, same specification, and same specification revision. The detail specification for the item will contain the official lot definition.

3.2 Item. The term "item", as used herein, refers to all types of flash munitions, flash bombs, and pyrotechnics.

3.3 Photocell. A photometric transducer for conversion of light energy directly into electrical energy.

3.4 Phototube. A photoelectric cell of the photoemissive type in which light impinging on a metallic cathode causes the emission of electrons.

3.5 Integrator. The term "integrator", as used herein, refers to an electronic instrument which automatically integrates the light energy of a flash, with respect to time, during the desired time interval of the flash (see 6.1.1 and 6.1.2).

3.6 I.C.I. International Commission on Illumination. An international organization which has set up standards of evaluation for the determination of luminous intensities and color. The term I. C. I. is more recently referred to as C. I. E. and is identical.

3.7 C. I. E. French title of the Intimation Committee for Lighting Standards, Commission International De L'Eclairage. See also I.C.I. above (3.6).

3.8 C. I. E. filters. Specially selected, two-element filters which convert the spectral response of a photocell to that of a C. I. E. observer.

3.9 C. I. E. observer. A colorimetric standard embodying the reaction of the normal eye to colors.

3.10 Neutral filters. Filters which are neutral from approximately 4,000 to 7,000 Angstroms (the visual range) in the wavelength band. These filters are employed to decrease the intensity of light falling on photocells, to a level within the linear range of response of the individual photocell.

3.11 Standard lamp. Referred to as a primary standard lamp, this lamp is a tungsten filament lamp selected and calibrated by the National Bureau of Standards (NBS). Each lamp is certified as to the voltage and current ratings required to obtain a color temperature of 2854°K. The candlepower of the lamp at this color temperature is also certified.

3.12 Working standard lamp. Referred to as a secondary working standard lamp, this lamp is a tungsten filament lamp, specially selected and calibrated against an NBS primary standard lamp.

3.13 Illuminometer. An instrument for measuring incident light consisting of a micro-ammeter (hereinafter referred to as the meter) calibrated in foot-candles, and a barrier layer cell pick-up (referred to as the target) corrected to a C. I. E. observer response by means of a viscor filter.

3.14 Cardinal point. A definite, marked division on the scale of the illuminometer meter.

4. GENERAL REQUIREMENTS OR STATEMENTS NOT APPLICABLE

5. DETAILED REQUIREMENTS OR STATEMENTS

5.1 Description of test.

5.1.1 The test consists of the determination of the light characteristics of the flash produced by the static explosion of the item, and comparison of characteristics with the criterion necessary for acceptance, as specified in the specification for the specific item.

5.1.2 The time-intensity characteristics of the light flash are recorded by means of a photocell-oscilloscope-camera combination as follows: The output of a vacuum photocell is coupled to a cathode-ray oscilloscope; the voltage deflection obtained is proportional to the illumination falling on the cell. This voltage is recorded, using a moving-film technique. The film-record can be analyzed to determine the flash characteristics of the item.

5.1.3 For acceptance of items requiring a measurement of integral light in the first 40 milliseconds of the flash, an automatic integrator is used.

5.1.14 Two types of flight integrators have been developed. In one me, (see 6.1.1 and fig. 1) the current from a vacuum photocell is allowed to charge a capacitor for the period of integration. This capacitor charge, which is proportional to the quantity of light, is indicated by an electrometer. In the second@ of integrator (see 6.1.2), the current from the photocell is converted to voltage pulses whose frequency is proportional to the intensity of the light. The pulses, in the first 40-millisecond period, are recorded on an electronic counter.

5.2 Criteria for passing test.

5.2.1 The sample shall comply with the criterion for acceptability as specified in the specification (s) for the item.

5.3 Equipment.

5.3.1 *Photocell.* A vacuum type phototube contained in a housing (Drawings P--72142, P–72143, and P–72144) is required which shall have a sensitive surface with a spectral response which can be corrected by the use of filters, to make it substantially equivalent to that of the C. I. E. observer.

The phototube shall have the following additional characteristics:

Spectral response:	S-7, or S-10.
Sensitivity without C. I. E. filter):	0.1 to 0.6 microamperes per foot-candle. (Light source, tunguten lamp at 2864°K.) .
Anode supply voltage:	100 to 150 volts dc, or suf ficient to reach voltage saturation for the phototube so that the output current will he linear with respect to incident light.

Stability:	Capable of delivering 5 microampere for an 8-hour period, upon exposure to a constant light source, with no more than 1 percent maximum change in output current.
Temperature coefficient:	Shall be determined, and must be as low as possible, since the sensitivity changes with temperature.

See 6.2.1 of this standard for general information concerning types of phototubes which have been found to be satisfactory.

5.3.2 *C. I. E. filters.* A specially selected two-element glass filter is required for each photocell, to convert the spectral response of the photocell so that it is equivalent to that of the C. I. E. observer. Refer to section 5.7 for the procedure to match a cell-filter combination.

5.3.3 *Neutral filters.* Filters which are neutral, throughout the wavelength band from 4,000 to 7,000 Angstroms, are required to decrease the intensity of the light falling on the photocells to the calibration level, and to prevent saturation. See sections 5.5 and 5.6 for the procedure to construct and calibrate a set of filters for each cell-housing combination.

5.3.4 *Standard lamps.* These lamps must be calibrated by the National Bureau of Standards (NBS) and certified as to their voltage, current, and candlepower rating at a color temperature of 2854°K. Airway beacon or projector lamps having tungsten filaments, and ratings of 1,000 to 1,500 watt, are suitable as light sources for calibration of the photocells. Secondary working standard lamps can be made by calibration against an NBS standard lamp. See section 5.9 for the selection and calibration procedure for secondary working lamps.

5.3.5 *Light integrator.* An automatic light-integrator shall be used when it is required that the integral light in the first 40 milliseconds of flash be measured. The integrator shall adhere to the following requirement:

Overall accuracy:	±2 percent in 40 millisecond period.
Timing accuracy:	40±0.2 milliseconds.
Starting delay time:	0.2 milliseconds, maximum.
Zero drift:	1 percent in 2 minutes, maximum.
Calibration drift:	±1 percent in 8 hour period.
Sensitivity:	1 by 10-8 ampere seconds per count or meter division.

See 6.1.1 and 6.1.2 for the description of integrators which have been found to be satisfactory for this test.

5.3.6 *Cathode-ray oscilloscope.* The cathode-ray oscilloscope shall be of the multi-channel type, and be equipped with an oscillograph-record camera to record the output of the photocells as received by the oscilloscope. The oscilloscope shall adhere to the following requirements:

Cathode-ray tube:	Five inch.
	2 or 4 gun with P–11 (blue, short-persistence) phosphor. Horizontal deflecton not to deviate more than ±2 percent vertcally over a 4-inch deflection.
Frequency range:	0 to 100kc±1 decible (db).
Stability:	Less than 1 millivolt drift for any one-minute interval.
Z-axis input:	Capacitive coupled input to the cathode of the cathode-ray tube.

5.3.7 *Oscillograph-record camera.* The complete camera assembly shall include the following:

85-mm strip or drum camera.
Lens and shutter.
Film speed control unit
Adapters and mount
Cables.
Data unit

In addition, the camera shall have:

Film speed:	Variable from 1 inch to 3,600 inches per minute.
Exposure capacity:	Single frame, up to 100 feet.

5.3.8 *Audio oscillator.* The output of an audio oscillator shall be coupled to the Z-axis input of the oscilloscope so as to produce timing marks on the film record. The audio oscillator shall adhere to the following requirements:

Frequency rating:	Oscillator must be capable of supplying a sine-wave signal of 1,000 cps (cycles per second) with an accuracy of 0.1 percent, and a frequency stability of 0.1 percent for a 20°C. change in temperature.
Output voltage:	25 volts, open circuit voltage.

5.3.9 *Voltage regulator.* The ac line voltage shall not vary more than ± .01 percent. A voltage regulator shall be used for the standard lamp and oscilloscope. The regulator shall comply with following requirements:

Input voltage:	100 to 130 volts ac, single phase, 55 to 65 cps.
Output voltage:	115 volts ac.
Regulation accuracy (commercial specifications):	±.01 percent for a variation in input voltage of ±10 percent and ±.01 percent for a load change of 100 percent.

5.3.10 *Standurd voltmeter.* A standard voltmeter is required to measure the voltage of the standard lamp. The voltmeter shall adhere to the following requirements:

Range:	0 to 150 volts ac.
Accuracy:	0.1 of 1 percent of full scale.

5.3.11 *Standard ammeter.* A standard ammeter is required to measure the current in the standard lamp. The ammeter shall adhere to the following requirements:

Range:	0 to 10 amperes ac.
Accuracy:	0.1 of 1 percent of full scale.

5.4 **Test procedure.**

5.4.1 *Test conditions.*

5.4.1.1 The tests shall be conducted only in clear weather, either during the day or night. Items shall not be tested when snow is present on the ground, or when the nature of the background will cause reflection of the flash. The transmission of the atmosphere shall be 92 percent, minimum, for a path of 1,000 feet.

5.4.1.2 The transmission can be determined by measuring the maximum distance that a large object can be seen in daylight against the horizon-sky background. This measure of visibility can then be converted to transmission by use of the International Daylight Visibility Table (see 6.1.3).

5.4.1.3 A group of trees, buildings, or water tower on the horizon, may be used as a sighting target. The target shall be considered to be visible when the outline of the object can be seen when the eye has become adapted to the prevailing light condition. A transmission of 92 percent, over a 1,000 foot test distance, corresponds to a daylight visual range of approximately 8 miles. Therefore, tests shall not be conducted when the visibility is less than 8 miles.

5.4.1.4 The item to be tested shall be suspended at an appropriate height so that the flash does not strike the ground. The photometers shall be at an adequate distance from the item so that the photocell light-shield will cover the entire area of the flash (see fig. 2). The area of ground viewed by the photocells shall be kept at a minimum to minimize pick-up of reflected light. The use of two photocells is recommended, so that a check of the results will be possible.

5.4.1.5 In general, the flash is observed from a position parallel to the axis and toward the nose of the item (end on). However, measurements are occasionally required from positions perpendicular to the axis (side on) and parallel to the axis toward the back of the item (back on).

5.4.1.6 The orientation of the photometers, the distance of the photometer to item, and the suspension and firing procedure, is given in the specifications of the specific item to be tested.

5.4.2 *Equipment calibration.* The equipment calibration procedure consists of individual equipment unit-calibrations; followed by the overall calibration of interconnected units, as system-calibration. No attempt shall be made to perform the unit calibration, or the system calibration procedures, before a sufficient warm-up period has been observed. The oscilloscope, oscillator, and standard lamp shall be connected to a regulated power source of 115 volts 60 cycles. A 30 minute warm-up period shall be allowed for the oscilloscope. The standard lamp shall not be left on any longer than absolutely necessary to obtain the calibration, as its useful life for this purpose is 10 hours.

5.4.2.1 *Unit calibration.* The unit calibration procedure shall be complied with before attempting to assemble the units in the required test system. The units shall be calibrated in the following manner:

5.4.2.1.1 The linearity of the oscilloscope shall be checked before and after each test. This is done by applying known voltage steps to the oscilloscope and photographing the deflection. In addition, before each bomb is fired, a known voltage must be applied to the oscilloscope and recorded on the film record. Thus, any change in the oscilloscope amplifier characteristics will be recorded and corrections can be subsequently applied. The oscilloscope amplifiers shall be adjusted if they show non-linearity. If the amplifiers cannot be made linear, then correction factors shall be established, and applied to the data, to correct for the non-linearity.

5.4.2.1.2 The photocell characteristics shall be determined before and after each test because of possible changes in photocell characteristics. Photocell sensitivity will change with temperature, therefore the calibration should be conducted at the same temperature as the test. If this is not possible, the temperature coefficient of the photocell shall be determined, and corrections applied for temperature changes. Prior to the calibration, the approximate illumination which will fall on the cells during the testing of the item, shall be calculated as follows:

Assume that for the test the photocell will be placed 1,000 feet from a flash item having an estimated maximum peak candlepower of three billion. Then, using the basic equation of the inverse-square-law for illumination,

$$\text{illumination in foot candles} = \frac{\text{intensity in candles}}{(\text{Distance in feet})^2}$$

substituting values for this example:

$$\frac{3 \times 10^9 \text{ candles}}{(1{,}000)^2}$$

equals:

3,000 foot-candles.

To prevent photocell saturation, maintain photocell stability, and reduce the light level to that of the calibration lamp, the intensity of the flash (as received by the photocell) must be reduced to the order of 30 foot-candles (this value depends upon the sensitivity of the individual cell) so that the current output is limited to five microampere, maximum. In this instance, a neutral filter of one percent is required. To obtain 30 foot-candles from a standard lamp with a candlepower of 1500, the calibration distance is computed from the inverse-square-law relationship as follows:

$$\text{Calibration distance} = \sqrt{\frac{\text{Intensity in Candles}}{\text{Illumination in foot-candles}}}$$

substituting values for this example:

$$d = \sqrt{\frac{1500 \text{ candles}}{30 \text{ foot-candles}}}$$

7.07 feet

5.4.2.1.2.1 A standard lamp shall be mounted, in a dark room, at the previously calculated distance. The plane of the standard lamp filament shall be perpendicular to the optical axis of the photocell. All distance measurements shall be made from the center of the lamp filament to 'the cathode of the photocell with an accuracy of 0.05 feet. (In the case of the PJ-14B cell, the photometric point is usually determined to be at the "window" of the photocell.)

5.4.2.1.2.2 A sheet of black velvet cloth shall be hung behind, and to the sides of the standard lamp, to prevent the photocell from "seeing" any light reflected from walls or other surfaces.

5.4.2.1.2.3 Appropriate baffles shall be used, where specified by NBS, for the lamp being used. This is done so that the light coming from the lamp will be from the filament only, and not from the reflecting surfaces on the lamp bulb.

5.4.2.1.2.4 A precision voltmeter, and a precision ammeter, shall be connected in the lamp circuit as shown in figure 3. The current and voltage of the lamp shall be adjusted so that the lamp will operate within 0.25 percent of its rated current and voltage. For example, if the rated current for a lamp is specified as 7.30 amperes, the current shall be adjusted by means of the variable transformer so that the current does not differ from the rated value by more than 0.01 ampere. If the rated voltage is specified as 84.1 volts, the voltage across the lamp shall be adjusted so that it does not differ from the rated value by more than 0.2 volts. Depending upon the circuit the current drawn by the voltmeter shall be calculated and subtracted from the reading of the ammeter, or the voltage drop across the ammeter shall be computed and the voltmeter corrected accordingly.

5.4.2.1.2.5 If the simultaneous corrected readings of the voltmeter and the ammeter do not check with the values specified by NBS for the lamp under test, the lamp shall be replaced with another standard lamp. If the readings still do not check, either the voltmeter or ammeter, or both, are in error, and shall be recalibrated before proceeding with the test.

5.4.2.2 *System calibration.* Following the calibration of each unit of test equipment, the units shall be connected as a system to perform the requirements of the tests in this standard. The system shall be calibrated in the following manner.

5.4.2.2.1 The pre-calibrated instruments shall be connected to a 115 volt 60 cycle power source. A regulated power supply shall be used for the oscilloscope, the oscillator, and the standard lamp, allowing a 30 minute warm-up period for the oscilloscope.

5.4.2.2.2 The oscillator shall be set to 1,000 cps, and its output connected to the Z-axis input of one or more (as required) channels of the oscilloscope. This will provide timing dots on the film record.

5.4.2.2.3 The photocells shall be connected to the X-axis dc amplifiers of the oscilloscope. The connection shall be made using shielded cable not more than 30 feet in length. The capacitance of the cable shall not exceed 16 micro-microfarade per foot. The input resistante of the oscilloscope shall be shunted with a resistor, which will make the resulting resistance 0.2 megohms, maximum.

5.4.2.2.4 If more than 30 feet of shielded cable is required, a cathode follower shall be used with each photocell. Refer to section 5.8 for details of the cathode follower, coupling circuit, and cables.

5.4.2.2.5 The light from the pre-calibrated standard lamp shall be permitted to illuminate the photocell. The amplifier gain control of the oscilloscope shall be adjusted so that the deflection of the beam amounts to three-quarters to full scale on the face of the cathode-ray tube.

5.4.2.2.6 The deflection of the oscilloscope, produced by the standard lamp, shall be photographed. If the light intensity falling on the cell is 30 foot-candles, and the oscilloscope deflection, as measured on the film is 0.60 inches, the calibration factor of the system is calculated as follows:

$$\frac{30}{0.60} = 50 \text{ foot-candles per inch on the film.}$$

The standard lamp, shall not be left on any longer than absolutely necesary to obtain the calibration, as its useful life for this purpose is 10 hours. A record shall be kept of the burning time of the lamp, and after 10 hours the lamp shall be recalibrated. The photocells shall be kept covered at all times except when calibrating or testing. This is required in order to prevent fatigue and damage to the photosensitive surface of the photocell.

5.4.2.2.7 The linearity of the oscilloscope shall be checked, before and after each test, to comply with the requirements of 5.4.2.1.1.

5.4.2.2.8 The calibration of the system shall be checked at the beginning and the completion of each daily firing program. An average shall be made of the two calibrations, and this average used in the evaluation of the test data.

5.4.2.2.8.1 If the two calibrations differ by more than 2 percent, after corrections for amplifier drift are made, the result of the tests is in question, and the cause for this change shall be determined and remedied before further tests are conducted.

5.4.2.2.8.2 The most probable cause of such changes is a change in the characteristics of the oscilloscope amplifiers. Under these conditions, it is suggested that the oscilloscope amplifier tubes be replaced.

5.4.2.2.9 The linearity of the entire system shall be checked at weekly intervals. This is done by placing filters of known transmission in front of the photocell, or by applying the inverse-square-law and photographing the deflection on the oscilloscope. Filters of approximately 75, 50, and 30 percent can be used for this purpose.

5.4.2.2.9.1 If the oscilloscope shows a deviation from linearity of more than 2.5 percent, the system shall be investigated to determine the cause.

5.4.2.2.9.2 A check shall be made to determine that the photocell is not being saturated or operated on a non-linear portion of its voltage output characteristic curve (see 5.4.2.1.2).

5.4.2.2.9.3 The oscilloscope amplifiers shall be checked and re-adjusted if they show non-linearity (see 5.4.2.1.1).

5.4.3 *Procedure.* The details of the actual firing test procedure will be found in the specification applicable to the particular item.

5.4.4 *Recording the data.*

5.4.4.1 The oscilloscope-record camera (see fig. 4) shall be operated at a speed of 30 to 40 inches per second for flashes lasting less than one-quarter of a second (250 milliseconds). One second shall be allowed for the camera to attain speed before firing the item,

5.4.4.2 The film, in the oscillocope-record camera, moves in a vertical direction, and the beams deflect in a horizontal direction. This produces a time-intensity curve similar to that in figure 5.

5.4.4.3 If more than one recording channel is used, the beams shall be positioned so that there will be no difficulty in analyzing the film record.

5.4.4.4 The 1,000 cps signal from the audio oscillator shall be coupled to the Z-axis input of one channel, to give millisecond timing-dots on the film record to serve as a time-base.

5.4.5 *Analysis of recorded data.*

5.4.5.1 Time durations, intensity, and integral light can be determined from the time-intensity film record.

5.4.5.2 The film record shall be developed and enlarged from three to five times, to increase the accuracy of measurement.

5.4.5.3 The intensity of any given point on the time-intensity curve shall be calculated using the oscilloscope calibration, as follows:

$$\text{Intensity in candles} \quad \frac{I}{d^2} \text{X} \quad \frac{D^2}{t \times c} \quad \text{X1}$$

where:

I = Candle power of standard lamp.

d = Distance in feet from standard lamp to photocell during calibration.

D = Distance in feet from the item to photocell during test.

t = Transmission of neutral filter used to reduce the light from the item $\left(\frac{\text{Percent transmission}}{100}\right)$

c = Calibration deflection on the oscilloscope. This is the deflection distance in inches as measured on the film (or enlargement) of the beam of the oscilloscope caused by the light of intensity $\frac{1}{D^2}$ falling on the photocell during calibration. If this deflection is different for the calibration before and after the test, an average of the two shall be used for c.

1 = Distance on film (or enlargement) in inches between point on time-intensity curve and base line.

5.4.5.4 When integral light is used for acceptance criteria, the area under the time-intensity curve must be determined for the time period under consideration. This can be done by using a planimeter on the enlarged record, or by summing the ordinates of the curve at l-millisecond intervals during this period.

5.4.5.5 The factor, for converting the area under the time-intensity curve to integral light in terms of candle-seconds, shall be calculated as follows:

$$\text{Candle-seconds per square inch} = \frac{I}{d^2} \times \frac{D^2}{t \times c} \times \frac{M}{1{,}000}$$

where:

M = Time-to distance ratio along time base of film in milliseconds per inch. This is obtained by measuring the number of millisecond-dots for a known distance in inches on the film.

All other symbols within this calculation are as identified within 5.4.5.3.

5.4.5.6 An example of the calculation for determining the factor of candle-seconds per square inch, is as follows:

Assume:

Candle power of standard lamp (I) = 1500 candles

Calibration distance of standard lamp (d) = 7.07 feet

Deflection distance of oscilloscope beam in inches on film (c) = 0.69 inches

Time-to distance ratio on film (M) = 30 milliseconds per inch = 0.030 seconds per inch

Item test distance (D) = 1,000 feet

Transmission of neutral filter (t) = 1.00 percent = 0.01

Then, the factor for candle-seconds per square inch on the film, is as follows:

$$\text{Candle-seconds per square inch} = \frac{1500 \times 1 \times 10^6 \times 0.030}{(7.07)^2 \times 0.69 \times 0.01}$$

5.4.6 *Experimental procedure for operation of capacitor type integrator.*

5.4.6.1 Figure 1 illustrates the Model 2, 40 millisecond integrator, and figure 9 is a schematic diagram of the integrator. This integrator was designed and constructed by Picatinny Arsenal. For complete details refer to Picatinny Arsenal Technical Report No. 1930 (see 6.1.1).

5.4.6.2 Connect the integrator instrument line-cord to a power source of 110 volts 60 cycles. Set the power switch to ON and allow a 5 minute warm-up period before operating.

5.4.6.3 Operate the PUSH TO ZERO control, and then adjust the METER ZERO control so that the meter indicates exactly zero. This meter-zeroing procedure shall be repeated just before the item is fired, in order to obtain an accurate reading.

5.4.6.4 A lamp standardized for horizontal luminous intensity (emitting between 1,000 and 4,000 candles) shall be mounted in a dark room at a distance of from 10 to 50 feet from the integrating photocell. The lamp shall operate at a color temperature of 2854 °K. (± 8°K.)

5.4.6.4.1 A precision voltmeter and a precision ammeter shall be connected in the lamp circuit.

5.4.6.4.2 The lamp current shall be adjusted so that the lamp will operate within 0.25 percent of its rated current and voltage. The use and measurement technique pertaining to these lamps is the same as described in paragraphs 5.4.2.1.2.1 through 5.4.2.1.2.5.

5.4.6.4.3 The distance between the lamp and the window of the integrating photocell shall be adjusted so that the meter on the integrator will indicate between one-half to full scale when the integrator PRESS TO TRIGGER control is operated.

5.4.6.4.4 A sheet of black velvet shall be hung behind the lamp. The photocell housing shall be sighted so that the axis of the photocell is perpendicular to the filament of the standard lamp. All other surfaces, visible from the photocell, shall be covered by the black velvet.

5.4.6.5 The distance between the lamp and the window of the photocell shall be accurately measured to within 0.5 foot. The cell shall be triggered five times, with the lamp operating at its rated current. The five readings shall be noted and averaged.

5.4.6.6 The integrator meter factor shall be computed as follows:

$$\text{Meter factor} = \frac{(\text{Candle power of lamp}) \quad (0.040 \text{ seconds})}{(\text{Distance in feet})^2 \quad (\text{Meter reading})}$$

where:

(meter reading) = Average meter reading as obtained in 5.4.6.5

5.4.6.7 The timing of the integrator shall be checked at weekly intervals to determine if the relay (K-1) closes for the required period of 40 ± 0.2 milliseconds, when triggering. A chronograph shall be used to measure the timing.

5.4.6.7.1 The relay (K–1) shall be removed from its socket and placed in the timing socket. The chronograph and the triggering battery shall be connected to terminals Number 1, 2, and 3 located in the rear of the chassis.

5.4.6.7.2 The triggering of the timing circuit can be accomplished by two methods; first, by exposing the triggering cell to a change in light intensity, and second, by depressing the triggering switch on the chassis.

5.4.6.8 An appropriate neutral calibrated-filter is required for testing the item. Neutral filters reduce the light of the item to a level which can be indicated within the range of the integrator meter. Refer to section 5.5 for the details on the construction of neutral filters. The determination for selection of a filter is calculated as follows:

$$Q = \frac{Mf \times Mr}{T} \times 100 \ D^2$$

where:

Q = Integral light expressed in candle-seconds.

Mf = Meter factor expressed in foot-candle seconds per division.

Mr = Meter reading expressed in divisions.

T = Transmission of the filter expressed in percent.

D = Distance from item to photocell in feet.

Assume that the item to be tested has an integral luminous intensity of 100 by 10^6 candle-seconds in the first 40 milliseconds of flash, and the meter factor is 0.021 foot candle-seconds per division. Then, solving for the transmission of the filter required for a three-quarter scale reading (150 divisions) on the integrator meter, it is found that a three percent transmission filter is required to keep the meter reading on scale.

5.4.6.9 The integrating photocell, with the proper neutral filter and the triggering photocell shall be aimed at the item, and connected by means of a cable to the integrator.

5.4.6.10 When the item is tested in daylight or under conditions of high ambient light a correction shall be made.

5.4.6.10.1 Before testing the item, and after the operating instructions have been executed, the switch PRESS TO TRIGGER shall be pressed. This will trigger the timing circuit, normally accomplished by means of the triggering photocell. The meter indication for the integrated daylight shall be noted, and subtracted from the reading obtained during the actual test.

5.4.6.10.2 Occasionally it may be found that there is some drift before the integrator is triggered. This meter drift is normally corrected by means of a chassis potentiometer (located near the millisecond-relay, K-L).

5.4.6.10.3 If the drift is not corrected by the adjustment of the potentiometer, then either the relay (K–1), or its associated electron tube (type 1L4), is at fault.

5.4.6.10.4 To check the relay (K–1), it shall be removed from its socket and the spare relay, on the chassis, shall reinstalled. The procedure in 5.4.6.10.2 shall be repeated.

5.4.6.10.5 If the corrective procedure in 5.4.6.10.4 fails to correct the drift, then the electron tube (1L4) shall be replaced. A tube with low grid-current characteristics shall be used. Several tubes can be tried in the circuit in order to select one with desirable characteristics.

5.5 CONSTRUCTION OF NEUTRAL FILTERS WITH WIRE SCREEN FILTERS

5.5.1 *General.* Neutral filters are required for the reduction of the light from the flash item (fig. 6). The light shall be reduced to a level which can be recorded by phototubes without saturating them.

5.5.1.1 The required filters can be constructed of wire cloth woven from 18-8 stainless steel having a mesh size of 60 by 60 or 70 by 70. The wire mesh shall be blackened, by holding over a gas flame, to reduce light reflection and scattering.

5.5.1.2 The desired number of layers of wire mesh shall be placed between pieces of clear glass (Corning type or approved substantial equal) and sealed with an epoxylene adhesive binder (Armstrong A-2 or approved substantial equal).

5.5.1.3 Filters of different transmission can be made, using different numbers of layers of wire cloth cut at different angles. For example, a filter containing one thickness of 60 by 60 mesh, has a transmission of approximately 30 percent. Two layers of mesh, with wires of one layer oriented at 90 and 45 degrees with respect to the other layer, will produce a filter of approximately 10 percent. Three screens oriented at 90, 45, and 22 degrees will produce a filter of approximately three percent. Four screens oriented at 90, 45, 22 and 90 degrees will produce a filter of approximately 1 percent. Five screens oriented at 90, 45, 22, and 45 and 90 degrees will produce a filter of approximately 0.3 percent.

5.5.1.4 A set of wire screens shall be made and calibrated (see section 5.6), for each individual cell-housing combination, as the filter transmission may vary slightly with individual cell-housings.

5.6 CALIBRATION OF NEUTRAL FILTERS

5.6.1 *General.* The measurement of the luminous intensities of photoflash items presents the problem of reducing the light level of the photoflash item. The light output of the various items is so high relative to that of the standard calibrating lamp that in order to prevent phototube saturation, and to permit the use of the phototubes for all items, a series of calibrated neutral filters is necessary. Although increasing the distance would decrease the light intensity on the phototubes, the difficulty in obtaining large test distances, and the enormous errors caused by haze-scattering over large distances, necessitates the use of the neutral filter method to vary the range of the apparatus employed.

5.6.2 *Method.* The method of measuring the percent transmission of the neutral filters is as follows:

5.6.2.1 The characteristics of the phototube to be employed shall be determined. A well-regulated 1,000 watt tungsten lamp shall be set at a distance at which the phototube will not become fatigued.

5.6.2.2 A galvanometers and two resistance boxes shall be assembled as shown in figure 7. The galvanometers shall have a sensitivity of 0.1 microampere, minimum. The resistance boxes may be Shallcross No. 833 or approved substantial equal. The galvanometers may be a General Electric Type 246–G13 or approved substantial equal.

5.6.2.3 The precision of the measurements will vary directly with the magnitude of galvanometers deflection, the accuracy of the decade resistance boxes, and the regulation of the lamp voltage.

5.6.2.3.1 In order to facilitate reading the galvanometers, it shall be damped with suitably selected resistance values so as to produce near full-scale galvanometers deflections. This is accomplished by varying the settings of the resistance boxes (Rv_1 and Rv_2) so that the sum of their resistance will equal the critical damping resistance for the particular galvanometers employed.

5.6.2.3.2 The accuracy of the decade resistance boxes shall be 0.1 percent, minimum, in order to obtain precise measurements.

5.6.2.3.3 The regulation of the lamp voltage shall be adjusted so that the lamp will operate within 0.25 percent of its rated current and voltage (see 5.4.2.1.2.4).

5.6.2.4 The transmission of the filter shall be calculated as follows:

Equation (1) $i = i_1 + i_2$

Equation (2) $(Rv_1)\, i_1, = (Gr + Rv_2)\, i_2$

Equation (3) $i_1 = \left(\frac{Gr + Rv_2}{Rv_1}\right) i_2$

where:

Gr = Galvanometers resistance (internal).

i = Total current through photocell.

i_1 = Current through Rv_1 (galvanometers shunt).

i_2 = Current through Rv_2 (galvanometers series-damping resistor).

Rv_1 = Galvanometer shunt resistance (resistance box).

Rv_2 = Galvanometers series-damping resistance (resistance box).

substituting in equation (1) produces:

Equation (4) $i = i_2 \frac{(1 + Gr + Rv_2)}{Rv_1}$

5.6.2.4.1 The galvanometers deflection is proportional to i_2. The equation for this proportional relation is as follows:

$$i_2 = aG$$

where:

1_2 = Current through R, (galvanometers series-damping resistor).

a = A constant (sensitivity of the galvanometers).

G = Galvanometers deflection.

Then, substituting in equation (4) produces:

Equation (5) $i = \frac{(Rv_1 + Rv_2 + Gr)}{Rv_1} (aG)$

Therefore, using equation (5), the current from the phototube, with and without the neutral filter, can be determined. Then, substituting the values obtained from equation (5), in equation (6), the ratio of the currents with and without the filter, will give the percentage of transmission of the filter.

Equation (6) $\frac{i_F}{i}(100)$ = percent transmission of the filter

where:

i_F = Total current through phototube with the neutral filter in place.

i = Total current through phototube without the filter.

5.7 MATCHING C. I. E. FILTERS TO PHOTOCELLS

5.7.1 *General.* The candle power of photoflash items is measured, at the present time, by means of photocells having spectral response characteristics corrected to match the C. I. E. visibility curve (see 6.1.7). The C. I. E. (formerly designated I. C. I.) visibility curve (Y-function) is described in the Handbook of Calorimetry by A. C. Hardy (see 6.1.5). This is in agreement with United Kingdom practice, and in accordance with the procedures used at the National Bureau of Standards (U. S. A.).

5.7.2 Due to great differences in the spectral response of phototubes, even from the same manufactured lot, it is necessary to individually correct the spectral response of each photocell. The procedure used to correct the spectral response of photocells, so that sufficient accuracy may be obtained in the measurement of flash item characteristic, is as follows.

5.7.2.1 The correct filter type and thickness to be used with each type of photosensitive surface, to correct it to the C. I. E. "Y-function" (see 6.1.5), shall recomputed approximately. The approximate spectral response of the photocell surfaces and the tube characteristics will be required, and may be obtained from the manufacturer. The approximate transmission curves of the glass filters will also be required, and may be obtained from the manufacturer (see 6.1.6). This information can also be obtained from the National Bureau of Standards (see 6.1.4)

5.7.2.2 Assume the problem of correcting an S–7 surfaced photocell (PJ–14B) to the "Y-function" of the C. I. E. system.

5.7.2.2.1 A preliminary computation is made (see 5.7.2.1), and the following selection of filters is indicated: Corning Glass Filters, Specification No. 3-76, 3-77, and 4-76 (Corning Nos. 3304, 3307 and 9780), or approved substantial equal. The graduated thickness of these filters is from ½ to 2½ mm.

5.7.2.2.2 A group of 6-inch square, colored-glass filters is then obtained. These filters shall have been calibrated at 25°C. for percent of luminous transmission, with a standard lamp at a color temperature of 2854°K, by the National Bureau of Standards. This group shall include a minimum of three filters, as follows: Red, Corning No. 2412: Yellow, Corning No. 3486 and Green, Coming No. 4407, or approved substantial equals.

5.7.2.2.3 Using a circuit similar to that in figure 7, insert the proper correction filters, of the calculated thickness, in the filter housing of the photocell. These filters will then correct the response of this particular S–7 surface, to that of the "Y-function".

5.7.2.2.4 The response, of the now corrected photocell, shall be checked at 25°± 2°C. by inserting the 6-inch square glass ± filters between the standard lamp (2854°K.) and the photocell housing.

5.7.2.3 Assume, for example, that the NBS certified luminous transmission of the red filter (Coming No. 2412 in this instance) is 13.7 percent. Also assume that the current from the photocell as calculated in 5.6.2.4.1, with its correction filter, is 2.34 microampere, when exposed to the white-light of the 2854°K. lamp. Further assume that the current from the photocell, with its calculated correction filter, is 0.360 microampere, when exposed to the red light obtained from the same system, but with the red filter interposed. The percent of luminous transmission is then calculated as follows:

$$\text{Luminous transmission} = \frac{\text{Photocell reading with "Y" correction filter and colored glass filter}}{\text{Photocell reading with "Y" correction filter only.}}$$

Then, substituting values;

$$\frac{0.360}{234}(100) = 15.4 \text{ percent transmission}$$

Since this value of 15.4 percent is greater than the certified value of 13.7 percent, it is apparent that the preliminary photocell correction filter is passing too much red light. Therefore, the thickness of the green component of the correction filter is increased, in small increment, until the correct value for the percent of luminous transmission of the red filter is obtained.

5.7.2.4 Procedures similar to 5.7.2.3 shall be used to measure the percent of luminous transmission of the green and yellow filters. The thickness of the calculated components of the correction filters, shall be adjusted empirically until agreement within five percent of theNBS certified values is obtained, (i.e., a maximum error of 0.7 in a transmission factor of 13.7 percent).

5.8 COUPLING CIRCUIT AND CABLES

5.8.1 Acoupling circuit must be used when recording from remote locations where more than 30 feet of connecting cable is required (see 6.1.8).

5.8.2 The present cathode-follower coupling circuit (fig. 8) is constructed so as to attach directly to the rear of the photocell housing. This device is designed to eliminate excessive capacitance, and frequency attenuation, in long-lead shielded cables.

5.8.3. The calibration of a test system employing the cathode-follower, is identical to the calibration procedure as detailed in 5.4.2.2, with but one added requirement. The added requirement consists of electrically balancing the long-lead cable through the cathode-follower. This is accomplished simply by connecting the appropriately labeled terminals to the oscilloscope horizontal amplifier. With the photocell cathode in darkness, check to see that there is no deflection of the beam on the face of the cathode-ray tube. If deflection is noted, adjust the 5,000 ohm potentiometer, on the cathode-follower, so that the output of the coupling circuit is zero (no deflection of the oscilloscope beam when photocell is in darknes).

5.8.4 The present coupling circuit (fig.8) will accommodate 1,000 feet of shielded cable, with a maximum capacitance of 16 by 10–12 farads-per-foot, with approximately two to three percent attenuation at 1,000 cycles per second (CPS).

5.8.4.1 If longer cable is needed, it will be necessary to sacrifice some gain of the circuit by reducing the cathode resistance, and the bias battery voltage.

5.8.4.2 The 1L4 electron tube, in the cathode-follower, is a sharp cut-off pentode. Therefore, the grid voltage of the 1L4 shall not exceed 12 volts, so that the tube will operate in a linear region of its characteristic.

5.9 METHOD OF CALIBRATING SECONDARY WORKING STANDARD LAMPS

5.9.1 *General.* In order to establish a secondary or working standard lamp, it is necessary to obtain at least three lamps of approximately the same wattage rating which have been standardized by NBS for color temperature (2854°K.) and luminous intensity.

5.92 The test procedure consists of a comparator method to determine satisfactory values of color temperature and luminous intensity for the lamps to be employed as secondary working standard lamps.

5.9.3 The lamps selected to be employed as secondary working standards shall meet the overall calibration requirements as specified within this test procedure.

5.9.4 *Equipment.*

5.9.4.1 *Standard lamps.* At least three lamps of approximately the same wattage rating, which have been standardized by NBS for color temperature (2854°K.) and luminous intensity.

5.9.4.2 *Optical bench. See 6.2.2.*

5.9.4.3 *Voltage regulator. See 6.2.3.*

5.9.4.4 *Illuminometer.* Weston Model 756, or approved substantial equal.

5.9.4.5 *Rheostat.* A 10 ampere, 0-130 volts ac, fine adjusting rheostat.

5.9.4.6 *Ammeter.* Weston Model No. 326 or approved substantial equal. The accuracy shall be 0.1 percent, minimum.

5.9.4.7 *Voltmeter.* Weston Model No. 326, or approved substantial equal. The accuracy shall be 0.1 percent, minimum.

5.9.4.8 *Photometric wreening. See 6.2.4.*

5.9.5 *Procedure.*

5.9.5.1 The lamps to be standardized shall be carefuly selected to be certain that there are no flaws in the glass envelope, and that the filament is straight.

5.9.5.2 The lamps shall be aged by burning them at their rated voltage for two percent of their rated life. (The rated life shall be obtained from the manufacturer's catalog.) For example, a General Electric 1,000 watt, Type T–20, mogul bipost, aviation lamp, has an average life of 500 hours. Therefore, the lamp shall be burned for 10 hours before attempting to standardize it.

5.9.5.3 Two lines shall be etched on opposite sides on the lamp, in a plane at right angles to the plane of the filament. One of these lines shall be marked with a circle to designate the side of the lamp to be placed away from the target when measuring luminous intensity. These etched lines shall be used to insure that the filament will be in the same relative position each time the lamp is used. The lamp shall be sighted through, and the two lines shall be in line with the target.

5.9.5.4 Before determining the luminous intensity, the lamp shall be adjusted to a color temperature of 2854°K. This may be done in accordance with the method described by King, Snider and Hamburger (see 6.1.9) or visually by using the 9 by 13° double-trapezoid field of a Leeds and Northrup Lumner-Brodhum photometer, and comparing it with an NBS standard. It is advisable to use three different NBS standardized lamps in this determination. The current and voltage, required by each lamp to obtain the proper color temperature, shall be noted.

5.9.5.5 The luminous intensity can be determined after the requirements in 5.9.5.4 have been met. The luminous intensity determinations shall be made on an optical bench, using three primary (NBS standardized) standard lamps, and a satisfactory illuminometer. One primary lamp shall be placed at the end of the bench, and the illuminometer shall be placed at a suitable distance so that the illuminometer meter will indicate a cardinal point. This point shall be noted. The photometric screening shall be used so that only light from the lamp strikes the target. This is very important for the elimination of errors from reflected light. In addition, all of the light from the filament must strike the target. In order to check this, the eye shall be placed at each of the four corners of the target to make certain that the entire filament is visible from each corner of the target.

5.9.5.6 When the requirements in 5.9.5.5 have been met, the primary lamp shall be removed and one of the unknown lamps shall be oriented in its place. The distance from the lamp to the target shall be varied until the same cardinal point obtained and noted in 5.9.5.5 is indicated on the illuminometer meter. It shall be made certain that the photometric screening is adequate. The luminous intensity shall then be computed by means of the inverse-square-law (see 5.4.2.1.2). Three primary lamps shall be used, and the determinations shall be repeated independently within 24 hours, by another technician as a check against any possible errors, The voltage and current settings shall be checked closely, since a one percent change in voltage will cause a five percent change in the candle power of the lamp. If the calculated value of the candle power, based on any one of the primary standard lamps, differs from the mean value of the three calculated values, based on the three primary standards, by more than 1.0 percent, then either the calibration was faulty, or the primary standard lamps are no longer reliable. For example, the calculated candle power values of 1500, 1507, and 1520 are obtained for a secondary lamp. The permissible deviation is 1.0 percent (or 1507 by 0.01). This indicates that a 15 candle variation about the mean (1510 candles) exists. It is therefore apparent that this calibration is within the permissible experimental error, and that the calibrations of the primary lamps are still correct.

6. REFERENCES AND GENERAL INFORMATION

6.1 References.

6.1.1 A portable, capacitor-type integrator (Model 2) is explained in detail in the Picatinny Arsenal Technical Report No. 1930, Long Range Research on Pyrotechnics, "Development of a Portable Integrating Photometer for Photoflash Bomb Evaluation". The Model 2 Integrator (figs. 1 and 9) operates in the following manner:

A multivibrator circuit, triggered by a photocell, energizes a fast-acting relay (fig. 9, K-1) for exactly 40 milliseconds. The relay allows the current from a second C. I. E. corrected photocell to charge a capacitor for the period of integration. The charge on this capacitor, which is in the grid circuit of an electrometer tube, is proportional to the quantity of light falling on the photocell. The electrometer tube controls a bridge circuit containing a millimeter whose reading is proportional to the quantity of light, and which can be calibrated directly in candle-seconds by the use of a standard lamp (see 6.1.2).

6.1.2 The Model 3 Counter Integrator, and its operating principles, is described in detail in the Picatinny Arsenal Technical Report No. 2041. The Model 3 Counter Integrator is considered to be superior to the Model 2 Integrator (see 6.1.1), because it is independent of electron tube amplifier characteristics, thus making the circuit stable and free from drift. The Model 3 Integrator operates in the following manner:

An electron voltage-reference tube (R. C. A. Type 5651 in this instance) is connected in series with an electron phototube (R. C. A. Type 6217). When light falls on the phototube, the voltage-reference tube charges to its firing voltage and then discharges. Equal increments of light energy are thus converted to voltage pulses whose frequency is directly proportional to the light; intensity falling on the phototube. A multivibrator, triggered by a change in light level on a triggering photocell, controls a gating circuit which allows the pulses to pass for the period of integration. These pulses are recorded on a counter-chronograph.

6.1.3 The "International Daylight Visibility Table" is published in the Naval Research Laboratory Report No. H-2303.

6.1.4 "Colorimetry" by D. B. Judd, National Bureau of Standards Circular No. 478, March 1, 1950, U. S. Government Printing Office, Washington 25, D. C., describes the I. C. I. (more recently designated as C. I. E.) color system.

6.1.5 "Handbook of Calorimetry" by A. C. Hardy, Technology Press, Cambridge, Mass., describes the I. C. I. (more recently designated C. I. E.) color system visibility curve "Y-function".

6.1.6 Information concerning the transmission-factor of glass filters, may also be obtained from the Coming Glass Co., Corning, N. Y.

6.1.7 Guidance information, of value when matching C. I. E. filters to photocells, may be obtained from the Picatinny Arsenal Technical Report No. 1770.

6.1.8 Picatinny Arsenal Technical Report No. 1981, Long Range Research on Pyrotechnics, "Development of a Coupling Circuit for Photoflash Testing", describes the cathode-follower and its application to coupling circuits.

6.1.9 "A Physical Comparator for Color Temperature of Incandescent Lamps" by King, Snider, and Hamburger, Journal of the Optical Society of America, Volume 42, No. 3, Page 178, describes a procedure which may be used for adjusting the color temperature of lamps to be used as secondary standards.

6.2 General Information.

6.2.1 *Phototubes.* The following phototubes have been found satisfactory for the requirements of the tests within this standard:

Manufacturer	*Type*	*Application*
General Electric	PJ–14B	*Phototube

* Employed herein as simple phototubes by connecting the dynodes directly to the anode.

6.2.2 *Optical bench.* The Gaertner, 3 meter, optical bench, has been found to be satisfactory.

6.2.3 *Voltage regulator.* The Sorenson Voltage Regulator, Model 1001, has been found to be satisfactory.

6.2.4 *Photometric screening.* Photometric screening, or black velvet, shall be mounted on the optical bench to eliminate all external and reflected light.

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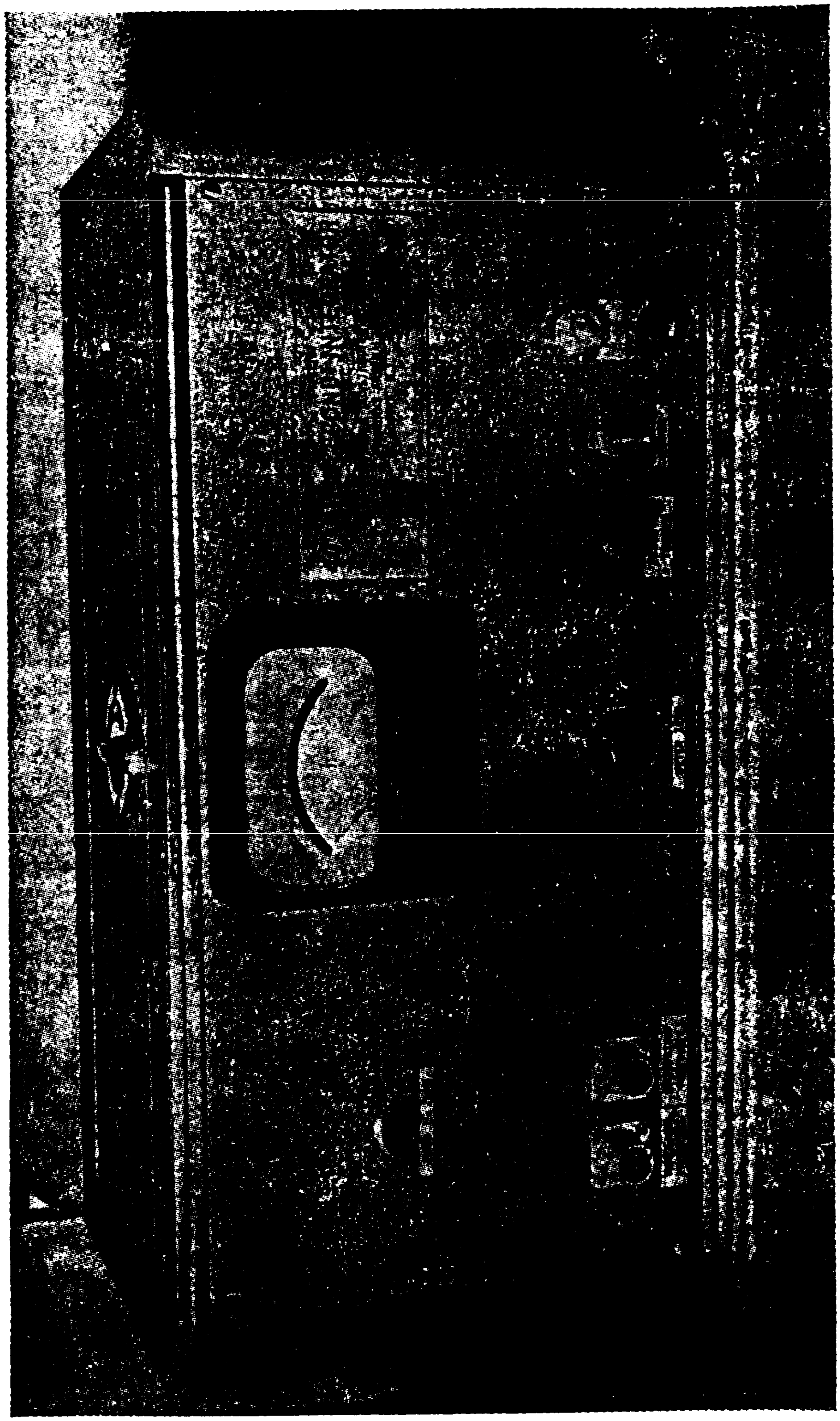

FIGURE 1. *Model 2—40 millisecond integrator.*

FIGURE 2. *Photocell housings and high speed camera used to measure and photograph time-intensity characteristics of photoflash bombs.*

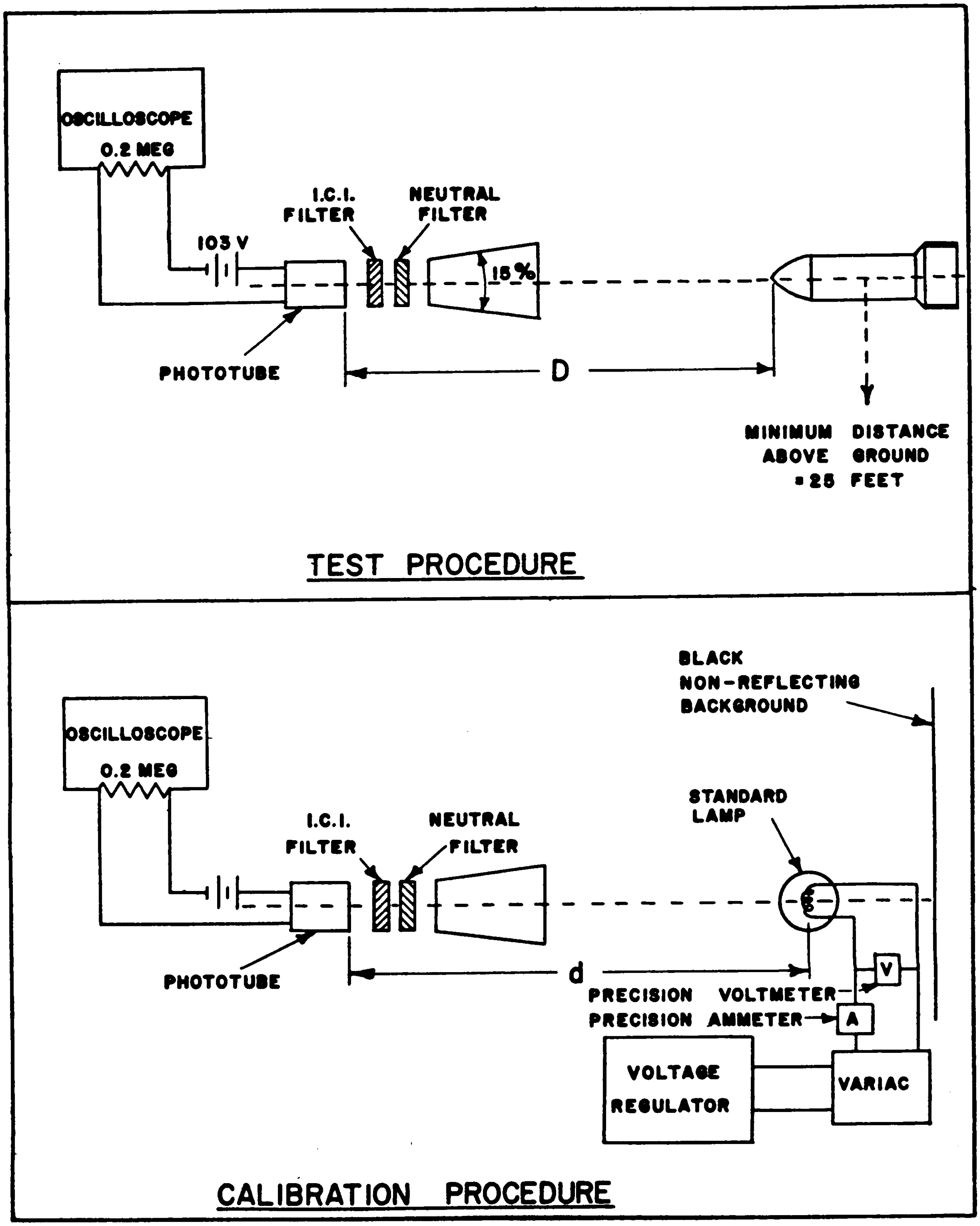

FIGURE 3. Test and calibration procedure.

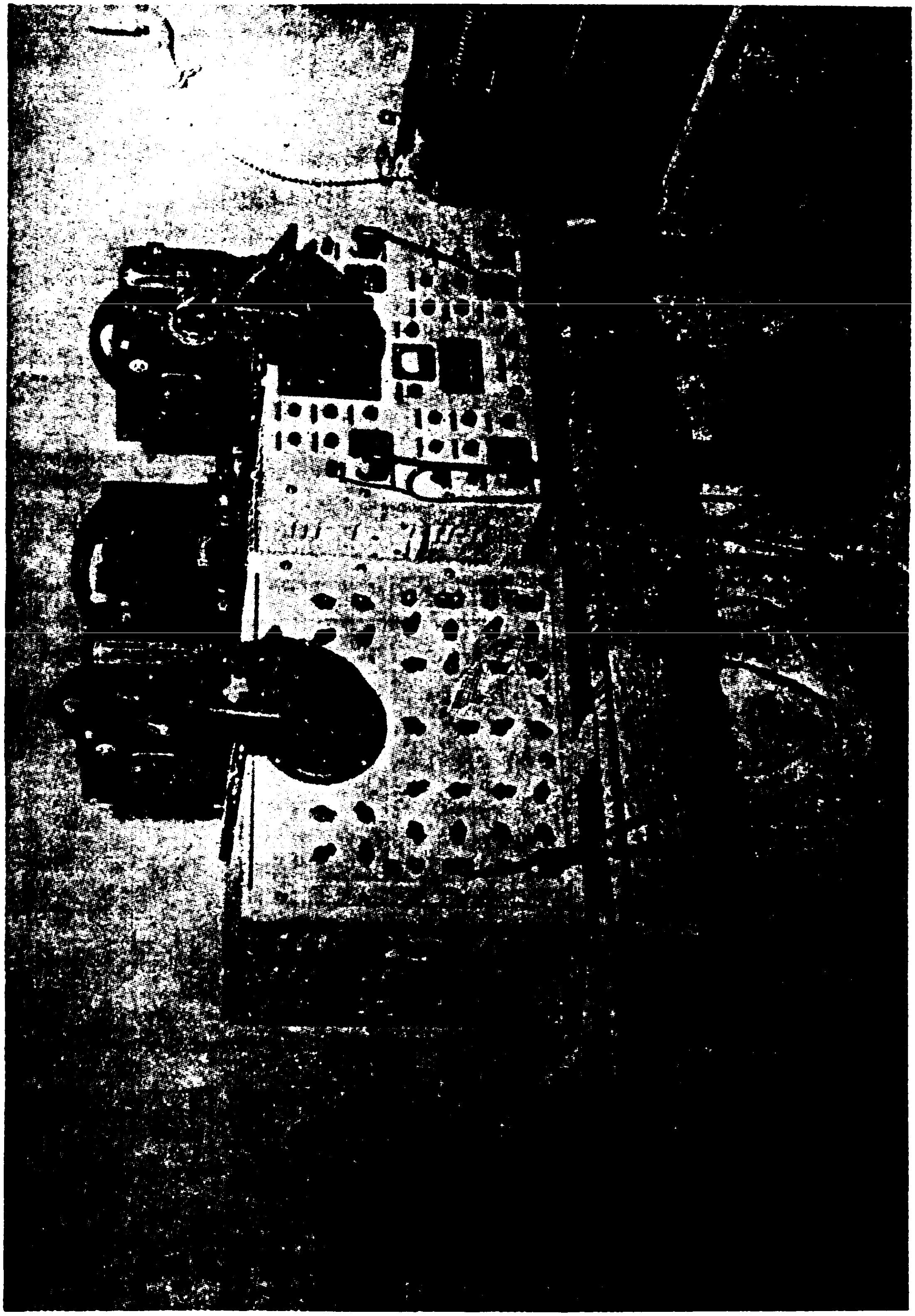

FIGURE 4. *Two channel and four channel oscilloscopes, cameras and oscillator used to record time-intensity traces of photoflash bombs.*

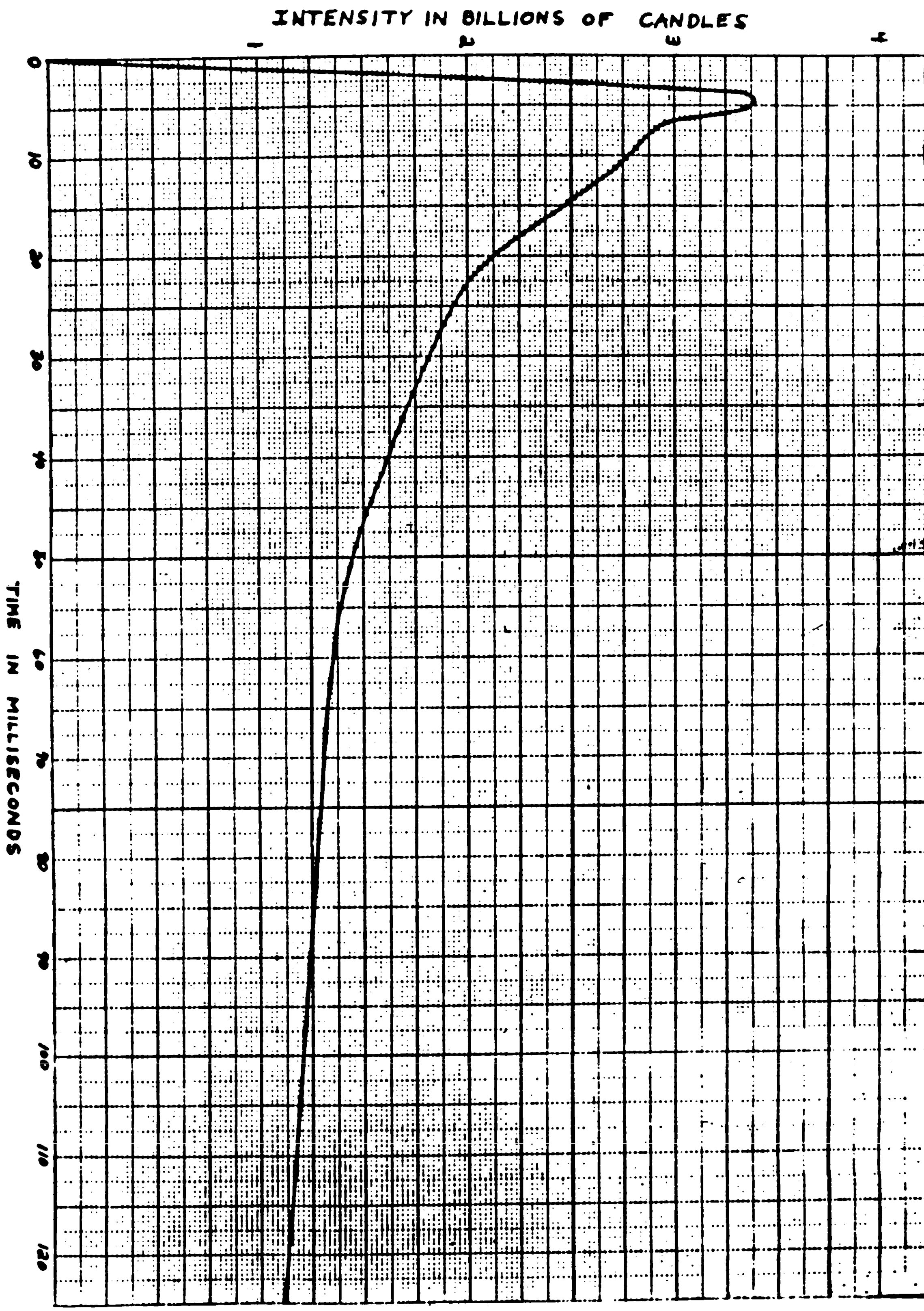

FIGURE 5. *Typical time intensity curve of M120 photoflash bomb.*

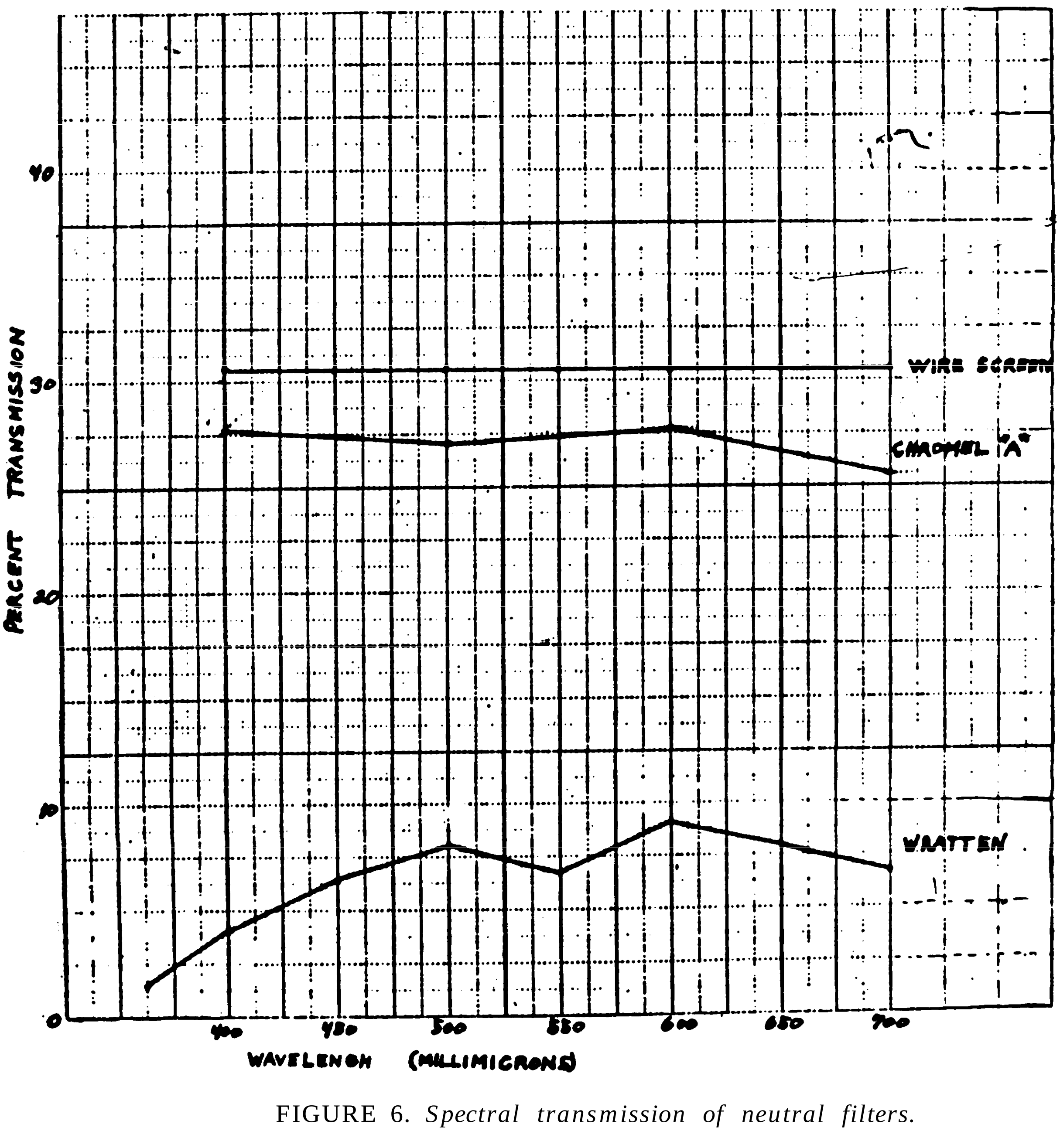

FIGURE 6. *Spectral transmission of neutral filters.*

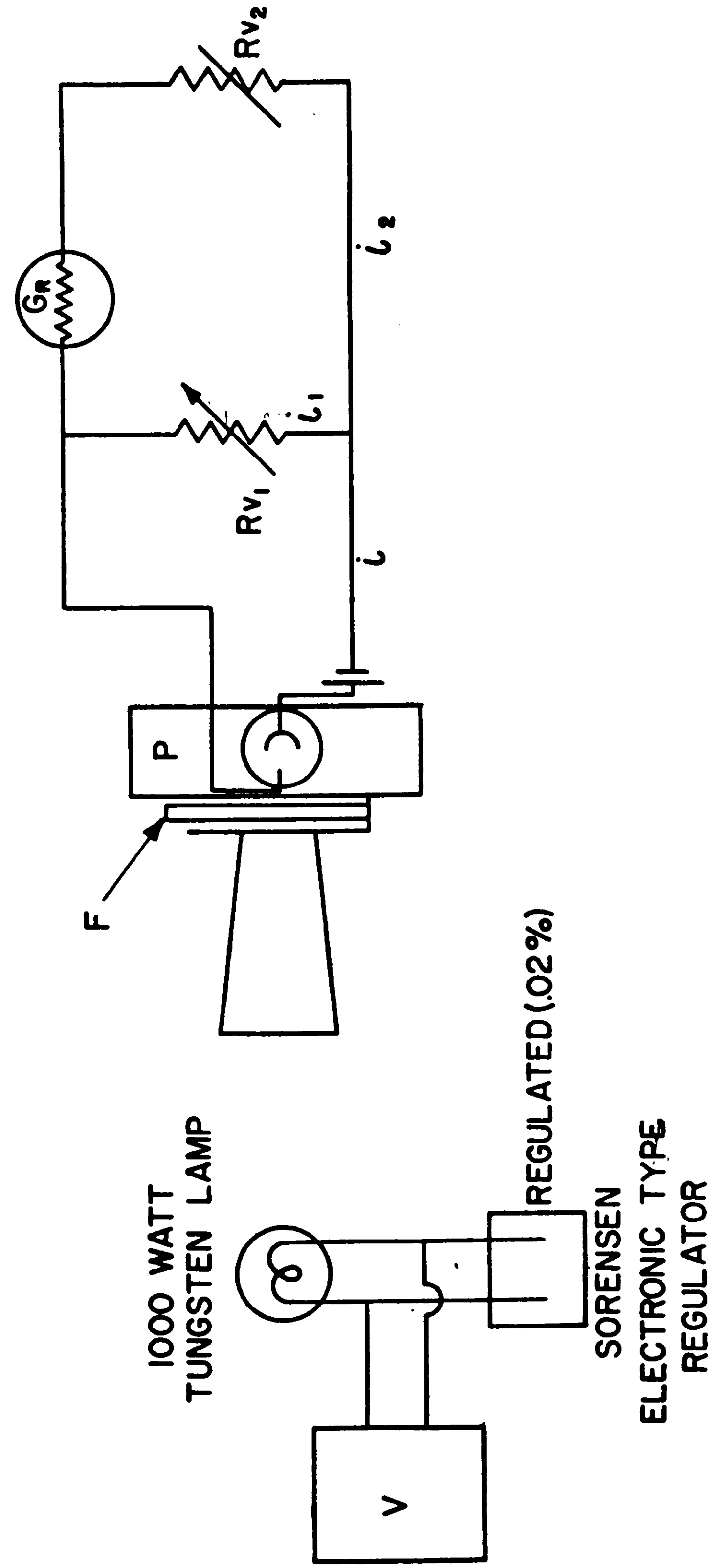

FIGURE 7. *Galvanometer setup for calibration of filters.*

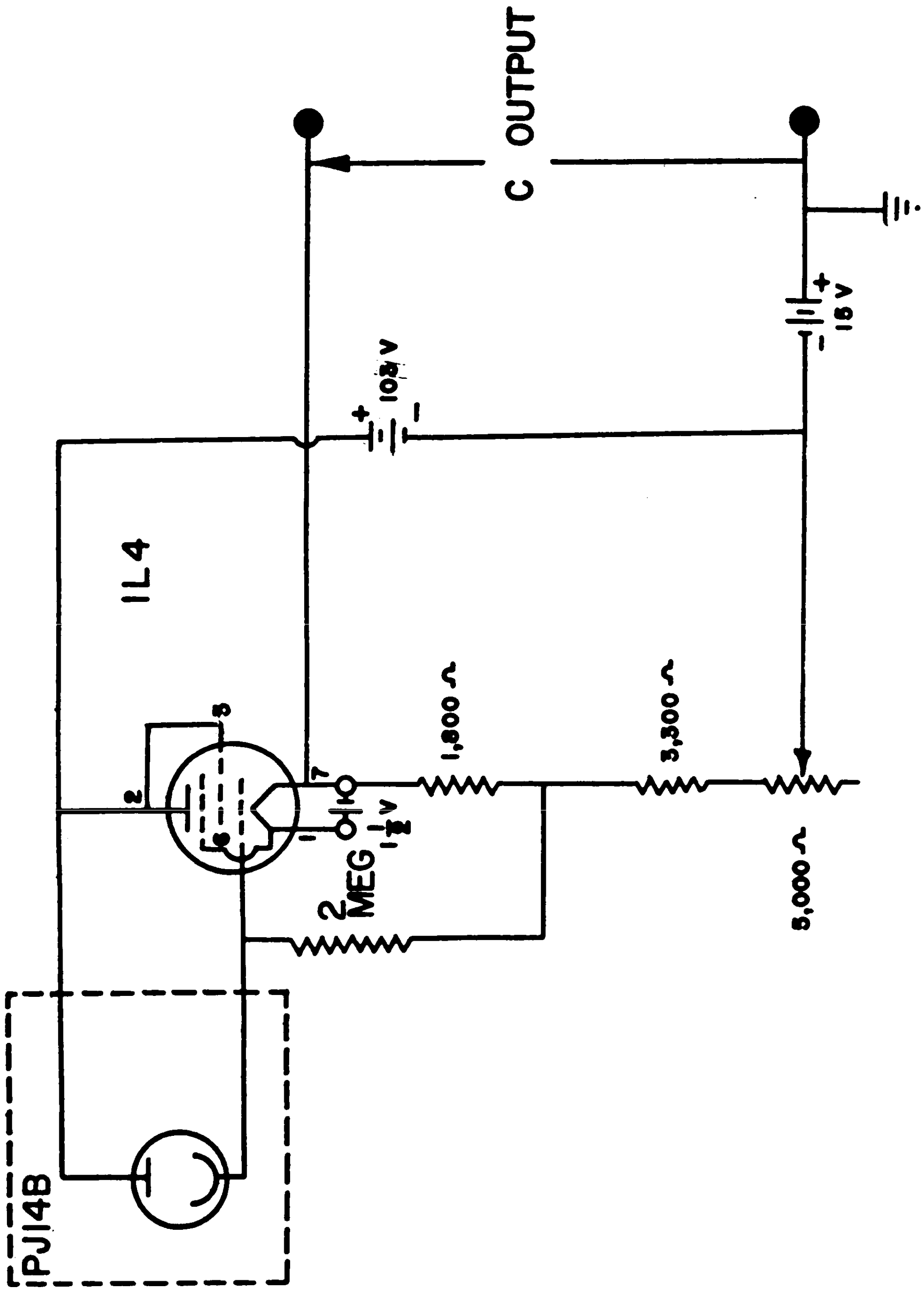

FIGURE 8. *Circuit diagram of photocell coupling circuit.*

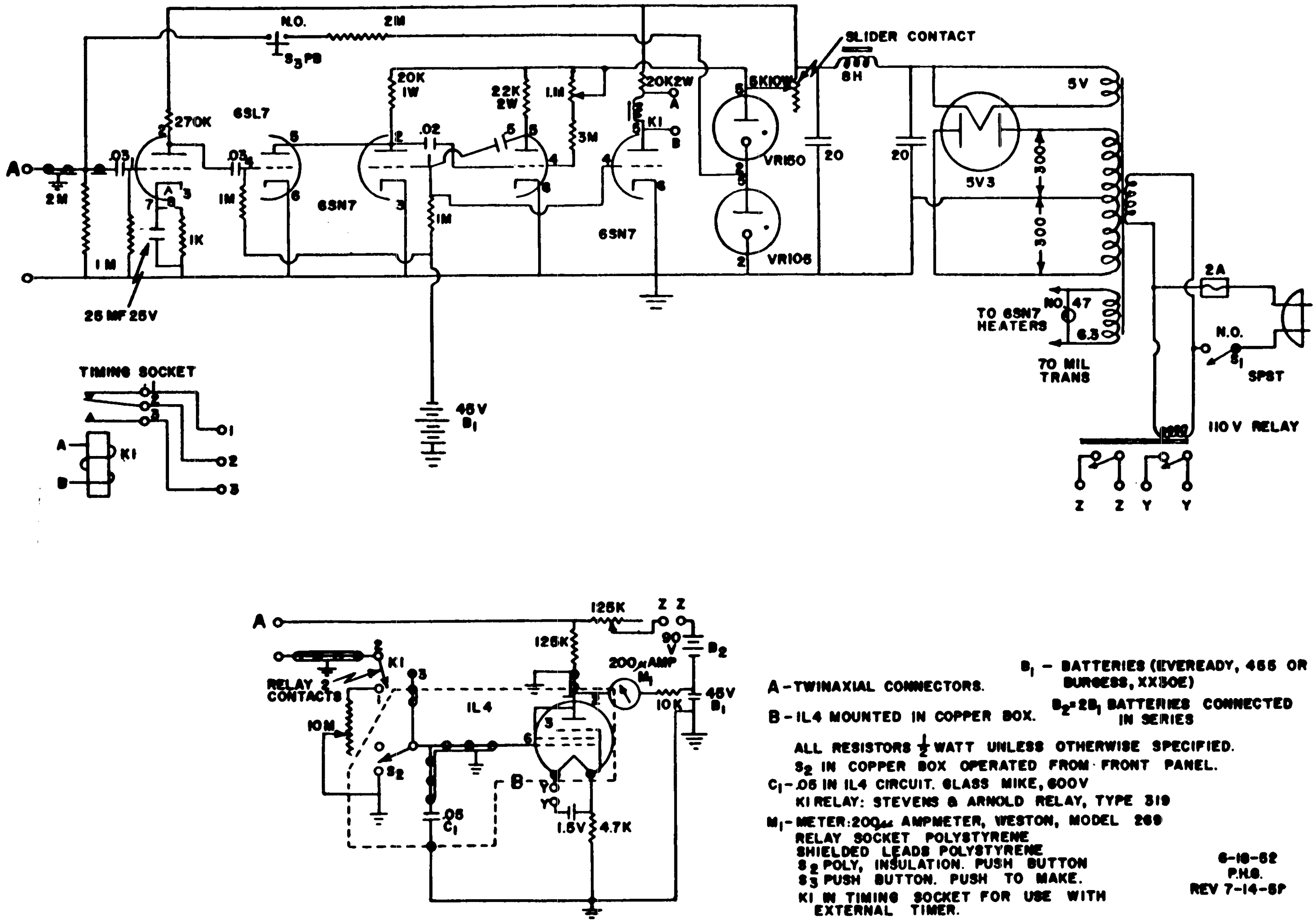

FIGURE 9. *Model 2—40 millisecond integrator.*