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Technical Manual for Phosphor Standards Calibrator

M. L. Greenough

Electronic–Optical Development Section
Measurement Engineering Division

and

H. K. Hammond, III

Laboratory Performance Section
Engineering and Product Standards Division

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August 12, 1974

Technical Report to

U. S. Postal Service
Equipment Development Division
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Preface

This report is in the form of a technical manual covering the theory and operation of an instrument for measuring the luminescent activity of the reference phosphor standards employed in the US Postal Service Model 4A Phosphormeters. The general design of the instrument follows that outlined in the final report on a prior project entitled "Development of phosphormeter standards, measurement techniques, and specification of solar cell characteristics, NBS Report 10 596". This technical manual together with the companion report, "Preparation and calibration of phosphormeter standards, NBS Report 74 553", and the Drawing Package, constitute the final report on the project sponsored by the Postal Service, Luminescence Calibration Equipment and Standards.

In addition to the listed authors, many others have made contributions to the work on the project. Especially among these should be mentioned Herbert D. Cook, who was responsible for developing the basic calibration technique. Credit should also be given for the work of L. F. Leach in the shop fabrication of the instrument.

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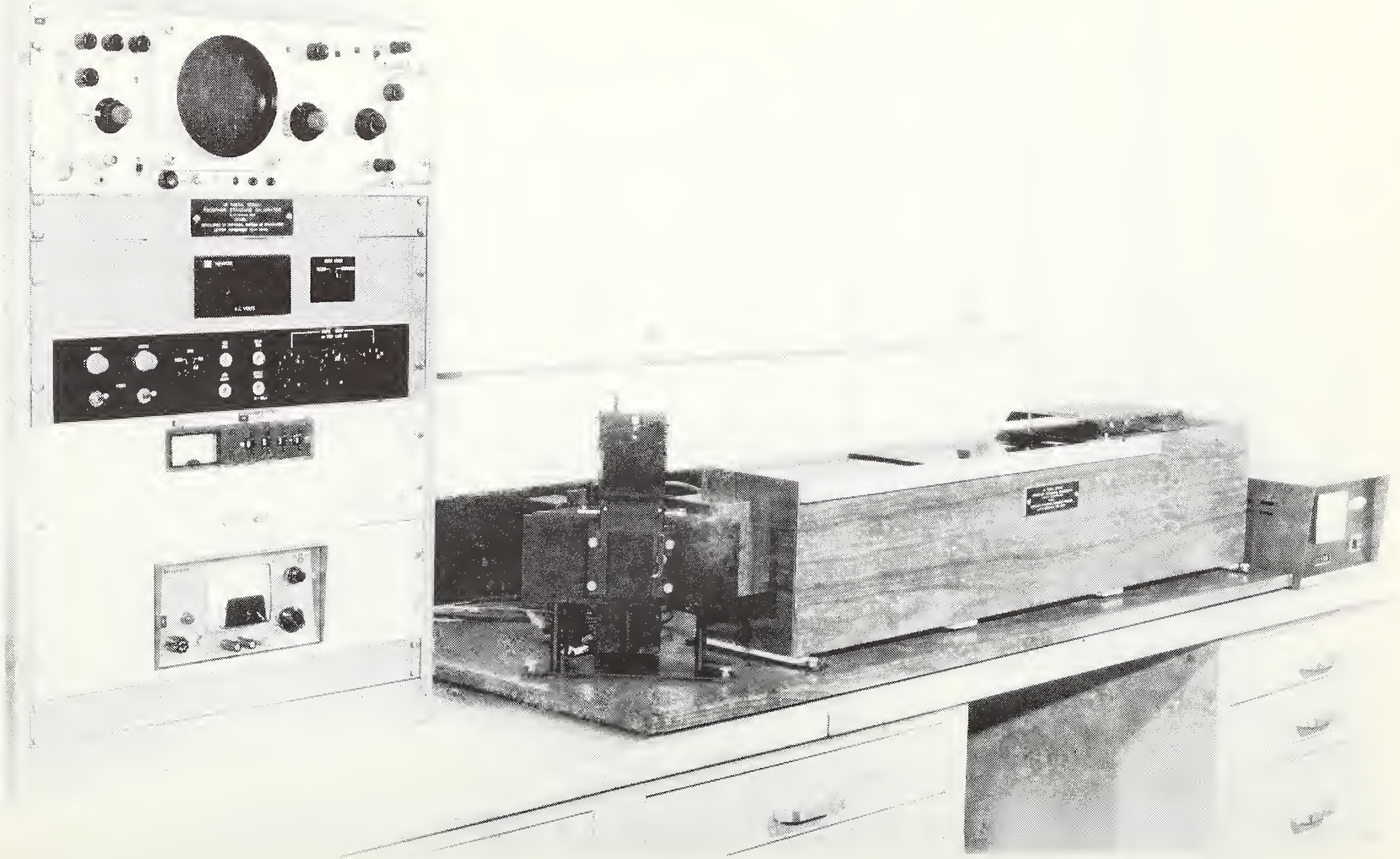


FRONTISPIECE NBS PHOSPHOR STANDARDS CALIBRATOR

1.0 Introduction

1.1 Function

The Phosphor Standards Calibrator is designed to measure the luminescent activity of USPS Phosphor Standards of the phosphorescent and fluorescent types. It is capable of operation in either of two modes, which are:

Comparator mode - Simplified operation whereby the resultant Phosphormeter unit (PMU) values are based upon direct comparison with immediately-available reference standards;

Calibrator mode - Operation based upon determining a factor called efficacy for each tested standard. Efficacy is then related to PMU value by previously-determined conversion constants based upon statistical evaluation of designated phosphor standards in prior use.

The difference between the two modes is that in the Calibrator mode, the long-term calibration of luminescent activity is referred to reproducible measurement of irradiance in watts per unit area at a given distance from ultraviolet and visible radiant sources. This is in contrast to the Comparator mode, which while more convenient, depends upon the measurement and preservation of potentially non-permanent physical standards. Whenever possible, however, the Calibrator mode, for which the instrument was primarily designed, is recommended for operation.

1.2 Specifications

Design range - 0.1 to 200 PMU nominal, extendable to 1000 PMU

Ultraviolet excitation - wavelength 253.7 nanometres (nm)
- duty cycle, ON for 10 milliseconds (ms); OFF for 90 ms, repeated cyclically

Spectral region of luminescent measurement - 450 to 650 nm

Measurement sample time - phosphorescence, 0.5 ms after extinction
- fluorescence, 0.5 ms before extinction

Output indication - analog on cathode ray oscilloscope
- digital, on digital panel meter 0.000 to 2.000 (volts)

Size of standards accepted - 3 x 4 x 7/16 inches (7.62 x 10.16 x 1.11 cm)

Size, inches and (centimetres)

Overall bench space - 88w x 24d (234 x 61 cm)

Measurement unit - 11w x 13.5h x 18d (28 x 34.3 x 45.7 cm)

Detector Calibrator unit - 46w x 9h x 7d (117 x 22.9 x 17.8 cm)

Power supply for Detector Calibrator - 10.5w x 6.5h x 15.5d (26.7 x 16.5 x 39.4 cm)

Electronics unit - 20.5w x 31h x 18d (52 x 78.8 x 45.7 cm)

Weight, approx, pounds and (kilograms)

Measurement unit - 10 (4.5 kg)

Detector Calibrator unit - 15 (6.8 kg)

Power Supply for Det. Cal. - 30 (13.6 kg)

Electronics unit - 75 (34 kg)

2.0 Theory of operation

2.1 General

This section includes a general outline of the calibration system for phosphor standards, covering the overall layout and operating principles. A photograph of the complete instrument is shown in Figure 1.

2.1a Instrument design

The overall plan of the NBS phosphor calibration system is shown in Figure 2. A more detailed view of the measurement system is given in Figure 3. The basic design of the instrument calls for irradiating the phosphor standard by a uv source at an angle of 45 degrees and detecting the emitted visible radiation with a photomultiplier tube (PMT) on an axis normal to the phosphor surface. Both the uv source and the PMT are located about 5 inches (125 nm) from the phosphor standard as it is held by the sample holder. Appropriate filters are located at the uv source (to pass only the 254-nanometre line of the low-pressure mercury lamp) and in front of the PMT (to block the reflected uv radiation). At the PMT a dual filter carriage arrangement is used, each carriage holding two filter assemblies as needed. Filter requirements are such that one carriage remains in the instrument while the other is interchanged according to whether green or red phosphorescence, or red or yellow fluorescence, is being measured. This filter arrangement is designed to provide rapid change of filters as needed in the measurement procedure.

On the other side of the PMT, also at 45 degrees from the normal to the standard, is a detector calibrator assembly whose purpose is to allow in situ calibration of the relative PMT sensitivity for ultraviolet and for visible radiation. The function of the detector calibrator assembly is to provide known irradiances at its exit port, both in the ultraviolet and in the visible regions. Irradiance measurements on a stabilized mercury vapor lamp have been carried out by the Optical Radiation Section of NBS. The lamp is to be recalibrated at periodic intervals, by comparison with an NBS standard of spectral irradiance, a 1000-watt quartz-halogen lamp. The PMT calibrator assembly is in a one-metre tunnel designed to hold the uv visible source(s) and to permit ready transference to the Optical Radiation laboratory.

The electronic portions of the system provide the waveform to excite the pulsed uv lamp used in phosphor measurement. This lamp is energized for 10 milliseconds and de-energized for 90 milliseconds on a repetitive basis. Reliable firing of the pulsed uv lamp is assured through the use of an envelope heater at 45°C and a nearby low-power, keep-alive lamp.

The measurement circuitry consists of a signal sampler which examines the PMT output current at the designated time, namely 0.5 millisecond after lamp extinction. Provision is made for changing this sampling time if desired. The sampled signal is further processed through peak-reading and electrical filtering networks to provide averaging over approximately 30 lamp flashes. This averaged current is displayed on a digital readout panel in illuminated numerals.

Physically the electronic components are located in a table-mounted rack cabinet which is located at the left of the optical measurement unit.

2.1b <u>Definition of efficacy</u>

Efficacy is the term applied to a dimensionless factor derived from the NBS instrument which is indicative of luminescent activity exhibited by phosphor standards. The concept of efficacy is in some ways similar to that of reflectance, where the light reflected (emitted, in the case of phosphors stimulated by ultraviolet radiation) from an illuminated specimen is compared to that from a perfectly diffusing surface. Thus efficacy may be regarded as reflectance with a wavelength shift, since the uv-irradiated specimen emits energy in the visible green or red portions of the spectrum.

The measurement of efficacy is a process of determining the ratio of two radiant power levels as received by a detector which is responsive to both uv and visible radiant energy. In the formula by which efficacy is calculated from observed readings, the radiant power reaching the detector is computed by dividing the measured detector current by its sensitivity in the appropriate wavelength region. The numeric value of efficacy can be expected to be rather small, since the emitted phosphorescent power in the visible portion of the spectrum is low compared to the diffusely reflected power in the uv region.

Efficacy as defined and measured by the NBS calibrator is essentially independent of the technique of measurement, with a single exception for phosphorescent (but not fluorescent) standards. Because of the energy-storage characteristics of phosphorescent materials, the magnitude of observed emission depends upon the length of time during which the phosphor is excited. Thus when a phosphor is excited, the luminescent output builds up in an exponential manner, decaying in the same manner when the excitation is removed. Hence the observed emission is a function of the duration of excitation as well as the interval between cessation of excitation to the time of measurement.

In the NBS calibration system, the duration and delay intervals have been selected as approximations to service conditions in the facer-cancelers and phosphormeters. The NBS calibration system uses a recurring excitation (duty cycle) of 10 milliseconds on and 90 milliseconds off, for a repetition rate of 10 per second. This allows the green phosphor to become very nearly fully charged and discharged, the red phosphor to charge to approximately 30 percent and to discharge almost completely.

The resultant is that the response to green phosphors is about 80 percent of the maximum possible, while that for the red is between 10 and 30 percent. Hence once the system has been calibrated to determine the conversion factor between measured efficacy and PMU, it is important to maintain the same duration of excitation and delay before measurement, as prevailed during the conversion process.

In contrast to measurements on phosphorescent standards, efficacy for fluorescent standards does not exhibit the time-dependent factor, provided certain conditions are met regarding minimum delay times. Therefore duty cycle and measurement times have virtually no effect upon the observed values of efficacy for fluorescent standards.

2.1c Measurement process

As mentioned in the definition of efficacy in Section 2.1b above, the measurement process is that of determining the incident power reaching the photodetector, under the two conditions of 1) visible emitted phosphorescence, and 2) uv reflection from a diffusing surface. These power levels are determined by measuring the output current of the detector and dividing it by the detector sensitivity at the specific wavelength region of interest.

Sensitivity in turn is provided through additional measurements of detector current when known levels of radiant power are introduced into the instrument. Since only the relative power levels (uv/visible) are involved in efficacy, many factors, which would otherwise have influence on the numeric value of efficacy are self-cancelling in the formula for its computation. Some of the cancelling factors are those relating to the angle of illumination (if it is identical with that for the detector calibration), the intensity of the pulsed uv lamp, the PMT gain, and the uv reflectance of the diffusing surface.

The procedure by which efficacy values are obtained involves four measurements under specified conditions, with prior calibration of uv and visible irradiances at the exit port of the detector calibrator, and of the reflectance in the visible region of a reference diffuse reflector. These are the basic factors involved in developing efficacy values from the NBS instrument; to these must be applied a pre-computed correction factor for the spectral response characteristic of the photomultiplier tube. The four measurements concerned with each tested standard enter the formula for efficacy as two ratios called Phosphor and Detector.

The Phosphor ratio is proportional to the phosphorescent activity of the standard; it involves two peak-sampled currents resulting from the use of the pulsed uv source in the Measurement unit. A Phosphor ratio is computed for every tested standard. The Detector ratio, which is indicative of the relative uv/visible sensitivity of the PMT, originates from the Detector Calibrator and involves averaged currents. It is usually necessary to measure the Detector ratio only once during a measurement session.

The manner in which these two ratios enter into the formula for efficacy, which in turn is convertible into PMU evaluations, is covered in Section 2.2c - Conversion to PMU values. The general procedure is to determine the effective PMU contribution which is proportional to efficacy, to which a minor correction constant is added. The final result for each phosphor standard is a working PMU value to which the phosphormeters must be set for evaluation of stamps and other luminescent materials.

2.2 Theory of operation, detailed

Specific details of design and operation are given in this section covering

a) Measurement unit

b) Detector Calibrator unit

c) Conversion to PMU values

d) Electronics unit

Step-by-step operating procedures are contained in Sections, 3 and 4 of this report.

2.2a Measurement unit

The major components of this unit are:

1) Housing

2) Pulsed uv lamp and ancillary equipment

3) Sample holders

4) Filter case

5) Photomultiplier tube, mount, and dark slide

6) Entrance port for Detector Calibrator

2.2a(1) Housing

The housing is the structure for holding the various components, principally optical, in the proper relative positions in the Measurement unit, as illustrated schematically in Figure 3 and photographically in Figure 4. Photographs of the partially disassembled housing show the front view in Figure 5 and the rear in Figure 6. The basic design consists of top and bottom plates, held together by a front plate, with three identical openings at the rear into which external appendages can be mounted. These external units are the pulsed uv lamp, filter carrier and PMT, etc. The sample holder is mounted at the center of the front plate.

The internal structure of the housing consists of three tunnel baffle assemblies having a common design, but which allow attachment of specific aperture plates as needed. These baffle assemblies are removable from the rear, as can be seen in Figure 6.

At the opening in the front where the sample holder has been removed, the front baffle assembly is visible in Figure 5. This assembly has three detachable aperture plates for optical access to the sample under test. Specifications for these plates are given under the descriptions of the specific components.

The top has a removable cover for physical access to the interior of the housing and to the mounting screws which hold the housing to the base plate.

2.2a(2) Pulsed uv lamp

Unless noted, the components described below can be seen in the photograph, Figure 7.

This is a commercial, pencil-type, low-pressure, mercury-vapor lamp similar to that used in phosphormeter and facer-canceler machines. Its principal emission is at 253.7 nanometres, with a secondarily strong emission at 546.1 nanometres and weaker emission at all the other mercury line wavelengths. Only the 254 nm line is used from the pulsed uv lamp; it will be noted later that the Detector Calibrator, employing the same type of lamp, utilizes both 254 and 546 nm wavelengths. The pulsed uv lamp is excited periodically at a duty cycle of 10 milliseconds on, 90 milliseconds off. During the time of excitation, a pulse of 570 volts through 40 000 ohms is applied to the lamp, resulting in a peak current of approximately 10 milliamperes. The emitted radiation reaching the standard under calibration is in the order of 20 microwatts per square centimetre.

The pulsed uv lamp is mounted in a thermally-insulated block of aluminum heated to approximately 45°C, to help insure precise repetition of pulsed radiation from the lamp. An electronic temperature controller, passing current through a 10-ohm resistor embedded in the block, serves to maintain the block temperature. Regulation is by means of a null-balance circuit, using positive and negative voltage supplies plus a thermistor whose resistance is 88 ohms at the design temperature. The exact temperature at which the lamp is controlled is not critical.

The exit port of the pulsed uv lamp house contains a removable aperture plate with an opening 1/8 inch wide by one inch (3.2 x 25.4 mm) high. Immediately in front of this, toward the test standard, is a slide shutter. In the up position, the shutter is closed and the uv radiation is blocked completely.

There is also an auxilliary mercury lamp designated a "keep-alive" lamp of the same type, mounted so as to radiate into the cavity where the pulsed lamp is located, but not into the exit aperture. It operates at a constant current of approximately 0.18 milliampere.

The uv-pass filter, whose function is to block all but the 254 nm emission of the pulsed lamp, is located just beyond the shutter for the pulsed lamp seen in Figure 6.

The radiation from the pulsed uv lamp is masked before it reaches the phosphor standard by the defining aperture plate which can be seen in Figure 5. As designed, the irradiated area on the phosphor standards is 0.5 inch (12.7 mm) wide, slightly narrower than the phosphor wafer. In height the irradiated zone extends from 1/16 inch (1.5 mm) above to 1/16 inch below the boundaries of the 1-1/2 inch (38.2 mm) vertical dimension of the wafers in the fluorescent standards.

2.2a(3) <u>Sample holder</u>

Two sample holders are provided, one to handle mounted phosphorescent and fluorescent standards, the other for unmounted samples such as coated paper sheets. The two holders are shown in Figure 8. The thickness of the front face on the two styles is such as to position the luminescent surface in the same plane of measurement, namely 0.25 inch (6.3 mm) from the front plate of the housing.

There are also two sizes of masks, one or the other of which must always be used. These are designed to match the wafer size in the phosphor standards. The smaller mask is for phosphorescence measurements; the larger, for fluorescence. There are small notches at the top right corner of the masks to facilitate their proper orientation with respect to the locating pins protruding from the front plate of the housing. For identification, the mask for phosphorescent standards has one notch, while the mask for fluorescent standards has two notches.

The sample holders can be interchanged readily, but each type of holder must be held in place with its specific mounting screws. There are four thumbscrews for the holder for phosphormeter standards and four flat head screws for the plate to be used with unmounted samples.

Before phosphormeter standards are inserted into the holder, the handle actuating the pressure plate should be turned down. Raising the handle then clamps the standard in the proper position for measurement. If the standard is removed with the handle upward, no harm will be done except for possible abrasion of the exterior. It is recommended that the handle be in the down position whenever a standard is inserted or removed.

2.2a(4) <u>Filter case</u>

This is the rectangular box which contains two movable carriages for holding the filters through which light must pass in order to reach the photomultiplier tube. The two carriages are designated Front and Rear, with the former closer to the sample holder. The overall filter case, its light-tight cover and one removed carriage are shown in Figure 9. In the mounted position, the handles of the two carriages protrude through the cover at the top of the filter case. Each carriage can hold two packages of 2 x 2 inch (50.8 mm) filters, one above the other, having a maximum thickness of 3/8 inch (9.6 mm) total thickness. In operation, selection of the required filter package is accomplished by raising or lowering the appropriate carriage. The filter package in use when the handle is raised, is the one farther from the handle. This can be seen in Figure 9. Spring-loaded mechanical detents in the carriages assure proper positioning of the filters in the optical path.

In normal operation of the system, the front filter carriage is loaded with fixed specific sets of filters. However, the filter in the rear carriage must be changed for each of the following operations:

1) Phosphorescence, green or red standards

2) Fluorescence, red channel

3) Fluorescence, yellow channel

These filters are to be inserted in the slot marked "VIS" of the rear carriage, the location farther from the handle.

Filter positions

The appropriate filters in their respective positions are listed below, together with their functions. All labeled filters should be positioned so that the labels are at the top and toward the sample holder.

Front carriage, UV position

This position carries an attenuator for reducing the effective sensitivity of the PMT to ultraviolet radiation by a factor of approximately 100. The exact attenuation is not critical, since the same factor is involved in the calibration of detector sensitivity. The initial attenuator is made of three sheets of fine wire mesh and one sheet of perforated stainless steel. This attenuator is not removed from the carriage.

Front carriage, VIS position

This position carries a permanently-installed combination of two filters, designed to block ultraviolet and infrared radiation, and to pass only visible light from about 450 to 650 nanometers. This filter insures that the detector receives only the intended visible emission from phosphorescent and fluorescent standards.

The filters in current use are a low-fluorescence, yellow glass filter labeled AJW 730515, 353 ADM, 26-414-5, followed by a short-wave-pass interference filter which transmits below 650 nm and blocks above this wavelength. The latter is marked LEI SWP-6500.

Rear carriage, UV position

Open, no filter

Rear carriage, VIS position

Single filters are to be placed in this position according to the type of measurement being made. In particular, this is to allow separate measurement of fluorescent standards respectively. The specific filters are:

1) Phosphorescence, either green or red - no filter

2) Fluorescence, red channel - marked F1, 39649-2
   This is a band-pass interference filter, with a width at half height of approximately 34 nm centered at 612 nanometres. Transmittance data for this filter are given in NBS Report 10 596 to the USPS entitled "Development of Phosphormeter Standards, Measurement Techniques, and Specification of Solar Cell Characteristics", 1971.

3) Fluorescence, yellow channel - marked B1, 39649-1
   This is a band-pass interference filter, with a width at half height of approximately 15 nm centered at 576 nanometres.

2.2a(5) Photomultiplier tube, mount, and slide shutter

This assembly bolts to the exit side of the filter case; the components are shown separately in the photograph, Figure 10. The PMT has an eleven-stage, "venetian blind" multiplier structure. The window is of fused silica, since the tube must detect radiation at 254 nanometres. The cathode sensitivity extends to 850 nm (10% of peak sensitivity) according to the manufacturer's data and independent measurements. Data on the spectral response of this tube are given in Monthly Report No. 3, Table 1 and Figure 2. It is designated as type 9558 QMA. While the PMT rating lists a maximum average anode current of 1000 microamperes, the actual current in the instrument is limited to 10 microamperes peak to minimize fatigue effects. The tube was supplied complete with magnetic shield and internally-contained voltage divider. Additional details on the PMT and its operation are included in Section 2.2d(6).

2.2a(6) Entrance port for Detector Calibrator

The entrance port can be seen in Figures 7 and 11. It is designed with an exterior shoulder to fit into the exit port of the Detector Calibrator unit. There is also a slide shutter to block radiation from the calibrator unit until needed. As with all other shutters, it is closed in the up position.

2.2b Detector Calibrator unit

This unit is a structure designed to hold the stabilized low-pressure mercury vapor lamp at a specified distance from the barium sulfate reflectance sample. At this distance (currently 90 centimetres) the irradiance has been measured in the Optical Radiation Section of NBS, for the 254 and 546 nm lines emitted by the lamp. In the formula for efficacy, derived later, it will be seen that it is the relative visible/uv irradiance ratio which is desired. While the distance is thus not critical, it is good practice to operate at the calibrated position. To facilitate positioning of the calibration lamp at any desired distance from the sample position, a metric scale is mounted on the side of the calibrator.

The photograph, Figure 11, shows an exterior view of the Detector Calibrator unit. Essentially it is a one-metre tunnel which contains a track-mounted mercury vapor lamp. It is fully baffled inside with removable aperture plates, to minimize internal reflections. There is also a holder for filters mounted in front of the lamp house. The bottom of the tunnel is arranged with a light-trap to admit air for the cooling fan associated with the lamp. Sliding cover sections plus a light-shielding cover over the ventilated lamp house serve to keep the ambient room light from affecting the calibrations.

Calibration performed on the lamp in free space with specific filters shows:

254 nm line - 0.502 microwatt per square centimetre with band pass interference filter marked "411.04"

546 nm line - 0.0788 microwatt per square centimetre with band pass interference filter marked "221.12"

The irradiance ratio, visible/uv, is 0.0788 divided by 0.502, or 0.1570.

2.2c <u>Conversion to PMU values</u>

The several steps which must be performed in order to evaluate phosphor standards in the NBS calibrator are listed below and described in sections 2.2c(1) through g which follow.

1) Determination of Phosphor ratio

This is the ratio of PMT output under two conditions of measurement with pulsed uv lamp. It is proportional to the luminescent activity of the phosphor standard. This ratio is determined for every standard being evaluated, either phosphorescent or fluorescent.

2) Determination of Detector ratio

This is the ratio of PMT outputs under the two conditions of measurement with the continuous-output lamp of the detector calibrator. It is proportional to the relative uv/visible sensitivity of the PMT. This ratio should be determined in every measurement session for phosphor standards, or at least once per week. The procedure is independent of whether phosphorescent or fluorescent standards are being measured.

In addition to Steps (1) and (2) above, pre-determination of certain other factors is required, resulting in a multiplying constant which must be recalculated from time to time on a long-term basis. These additional factors are:

3) Determination of Irradiance ratio

This ratio is indicative of the relative visible/uv irradiance provided by the detector calibrator unit. It should be measured every 100 hours of use of the lamp in the Detector Calibrator unit.

4) Determination of visible reflectance of barium sulfate standard.

This standard consists of barium sulfate powder under the quartz window of a phosphor wafer holder. Relatively infrequent measurement is required.

5) Determination of spectral response of the PMT and associated filters.

The relative spectral sensitivity of the PMT is expected to change slowly with time, requiring only infrequent checking or correction. Measurement of spectral sensitivity is difficult to carry out with high accuracy and so small changes will not be detectable with certainty.

From steps (4) and (5) a correction factor must be computed, equal to the ratio (4)/(5). In the event that the barium sulfate standard or the photomultiplier tube is replaced, introduction of the recomputed correction factor into the formula for efficacy which follows will compensate for any effects upon measured values. The next step is:

6) Computation of efficacy

Efficacy = (Phos. ratio)x(Det. ratio)x(Irrad. ratio)x(Corr. factor), where:

Phos. ratio = Ratio of PMT outputs with pulsed uv lamp = $\frac{\text{PMT output, visible}}{\text{PMT output, uv}}$

Det. ratio = Ratio of PMT outputs with Detector Calibrator = $\frac{\text{PMT output, 254 nm}}{\text{PMT output, 546 nm}}$

Irrad. ratio = Ratio of measured irradiances from Detector Calibrator = $\frac{\text{Irradiance, 546 nm}}{\text{Irradiance, 254 nm}}$

Corr. factor = $\frac{\text{Corr. for visible reflectance of barium sulfate std.}}{\text{Correction for spectral response of PMT and filters}}$

or:

$$\text{Efficacy} = \frac{(1) \times (2) \times (3) \times (4)}{(5)}$$

using results from the numbered steps above.

The result is a dimensionless factor expressing the emitted phosphorescent energy compared to that which a perfectly diffusing surface would reflect under the same conditions of uv illumination.

7) Conversion of efficacy to NBS-PMU values

This is the PMU evaluation of phosphor standard for the visual phosphorescent or fluorescent contribution only. NBS-PMU values are computed by multiplying the measured efficacy by a known conversion factor which has previously been determined from phosphor standards of assigned values.

The final step is:

8) Computation of tentative working values of PMU for phosphor standards.

To the NBS-PMU value derived in step (7) there must be added a correction constant C to take into account extraneous sources of response in the phosphormeters. For green phosphorescent standards, C = 1.0; for red, C = 8.0; for red fluorescent, C = zero. Since the correction constant C is difficult to evaluate, best-valuation estimates are in current use and the resultant working values are denoted NBS-PMU (T).

Because certain of the above eight items require more detailed comment than is provided in the step-by-step procedures listed in Sections 3 and 4, additional notes on these items are supplied immediately below.

2.2c(1) Phosphor ratio

This is the ratio of signal output when measuring the visible light emission of a phosphor standard, to the output when measuring the reflected ultraviolet from a barium sulfate reflectance sample. In order to minimize drift effects in the intensity of the pulsed uv lamp, it is necessary to measure the reflected uv both before and after any readings on phosphor standards. Furthermore, since the uv lamp does not always display a flat-topped pulse of uv output, it is also necessary to develop a weighted average intensity for the pulse. The weighting is designed to emphasize the amplitude toward the end of the pulse to simulate the storage action of phosphorescence. This is accomplished by sampling the instantaneous uv pulse signal at 10 time intervals during the pulse. Each sample is multiplied by a weighting factor which is largest for the sample at the end of the uv pulse. The sum of the weighted samples is then divided by the sum of the weighting factors to yield the uv pulse amplitude which is actually effective in the excitation of phosphorescent activity. If the uv pulse had a flat top, the weighted value would be equal to the instantaneous samples. However, when the pulse exhibits some decay, as is the normal case, the compensation for decay is introduced by using the weighting process.

Because the green and red phosphors have greatly different decay rates (3.6 vs. 22 milliseconds, for example, to decay to 1/e or 37%) it is necessary to compute separate effective uv pulse amplitudes for red and green phosphors, using two sets of weighting coefficients.

To reduce the labor of the weighting computations while meeting the requirement of before-and-after observation of uv pulse amplitude, it is recommended that measurement sessions follow this general pattern:

1) Measurement of the 10 samples of uv pulse amplitude

2) " green phssphorescent standards to be evaluated

3) " 10 samples of uv pulse amplitude

4) " red phosphorescent standards to be evaluated

5) " 10 samples of uv pulse amplitude

Computation, however, in items (1) and (5) can be reduced to that for green only and red only, respectively, if the above sequence is followed.

If there is a significant drift between the before-and-after pulse amplitudes it will be necessary to interpolate values according to the times of phosphorescence measurement compared to those of the uv pulse amplitude.

Because the luminescent emission of the phosphor standards is very small compared to the reflected uv from the barium sulfate reflectance standard, it is necessary to attenuate the latter by about 100 times to bring the PMT output within the range of the meter circuits. This is accomplished by placing a multi-layer mesh screen in front of the PMT whenever uv measurements are being made. Since this attenuator is also in the path during the uv phase of detector calibration, the attenuator transmittance cancels out in the product of Phosphor and Detector ratios, and so does not require separate determination.

2.2c(2) <u>Detector ratio</u>

This is the ratio of observed PMT output when the detector calibrator is operated separately with its pass-selection filters for the mercury 254 and 546 nanometre lines respectively. The ratio is obtained by noting the PMT output voltage when set up for uv emission from the detector calibrator, dividing this by the PMT output with the calibrator set for visible (546 nm) emission. Although the uv 254 nm uv line is strong in the mercury vapor lamp, the presence of the attenuator reduces the PMT output to less than 10 percent of the output from the 546 nanometre line. Typically the Detector ratio is in the order of 0.06 to 0.07.

Details of the procedural steps involved in determining the Detector ratio are given in Section 4. The determination of Detector ratio is not required when the system is used in the Comparator mode, since this mode employs only relative output indications.

2.2c(3) <u>Irradiance ratio</u>

The current value of this ratio of visible/uv irradiance, based upon the calibration performed in 1972, is 0.1570, as was derived in Section 2.2b - Detector calibrator. This value will be used until a recalibration gives a different value.

2.2c(4) Reflectance of barium sulfate standard

Two standards are necessary, one having a window area equal to that of the phosphorescent standards, the other equal to that of the fluorescent standards. The reflectances of these have been measured as 0.976 and 0.948 on an Automatic Color Brightness Tester. These measured reflectances take into account the losses due to the quartz window covering the barium sulfate surfaces.

Until the determination and final introduction of all filter characteristics, a temporary reflectance value of 1.00 has been assigned to the barium sulfate standards.

2.2c(5) Spectral response of PMT and filters

The purpose of PMT and filter factor is primarily to allow replacement of these elements without affecting the overall system's evaluation of phosphor standards. While not required for operation in the Comparator mode, the spectral response factor must be obtained in the Calibrator mode, where the evaluations of phosphor standards are referenced to the measured irradiance from the detector calibrator.

Quantitatively the spectral response factor is a numeric constant expressing the effect upon PMT output of distributing a given amount of radiant power over a spectral region matching that of the phosphorescent emission vs. concentrating the same power at the single wavelength of 546 nanometres. The relative PMT output for these two conditions is the spectral response factor.

The process of determining the spectral response factor is one of numeric integration, involving the spectral characteristics of the photomultiplier tube, the luminescent materials and any filters. Certain conditions are imposed upon these characteristics for use in computation; these are:

1) The relative spectral response function of the PMT is to be normalized to unity at 546 nanometres.

2) The relative spectral emittance function for a phosphor is to be adjusted so that the total area (sum of the ordinates throughout the region in which the phosphor emits) will be unity. An individual function is associated with each phosphor type.

3) Filter response characteristics are to be given in terms of spectral transmittance, always less than unity.

The above characteristics should be reported for wavelength intervals of 5 nanometres throughout the region covered by the useful phosphor output, or 450 to 870 nanometres.

The combined product (1) x (2) x (3) is to be computed for each wavelength, using in (2) and (3) the characteristics for each phosphor and filter as appropriate. The precise value at 546.1 nm should also be computed for (1) x (3) in order to establish the response at the wavelength of the detector calibrator source. The spectral response factor is obtained by summing of the products (1) x (2) x (3), and dividing the sum by (1) x (3) at 546.1 nanometres.

This computation of the sum of the products (1) x (2) x (3) at each wavelength is to be performed for the following specific combinations:

a) Green phosphorescent standards

In item (2) the emittance function for green phosphorescent standards is to be used. For item (3) it is the composite transmittance function for the uv-blocking and the infrared-blocking filters, since these two are always used together.

b) Red phosphorescent standards

Same as above except that (2) requires the red phosphorescent emittance function.

c) Red fluorescent standards, red channel

Item (2) requires the red fluorescent emittance function. Item (3) requires, in addition to the composite above, inclusion of the transmittance function for the red bandpass filter which is currently identified as F1.

d) Red fluorescent standards, yellow channel

Item (2) requires the yellow fluorescent emittance function. Item (3) requires in addition to the composite above, inclusion of the transmittance function for the yellow bandpass filter identified as B1.

e) Background fluorescent standards, red channel

Same as (c) above

f) Background fluorescent standards, yellow channel

Same as (d) above

The product (1) x (3) which is the response at 546.1 nm is required only once since the detector is always calibrated using the ultraviolet and infrared blocking filters, without the supplementary filters used in evaluations of fluorescent standards.

Typical spectral response factors are:

Standards	Typical values
Green phos.	1.004
Red phos.	0.641
Red fluor., red channel	0.324
Red fluor., yellow channel	0.0157
Bkgnd fluor., red channel	0.0129
Bkgnd fluor., yellow channel	0.310

2.2c(6) Computation of efficacy

Efficacy is to be computed for each phosphor standard being evaluated. While single values are found for the phosphorescent standards, dual values (red and yellow channels) are needed for fluorescent standards.

The formula for efficacy is:

$$\text{Efficacy} = \frac{\text{Phosphor ratio} \quad \text{Detector ratio} \quad \text{Irradiance ratio} \quad \text{Reflectance of barium sulfate std.}}{\text{Spectral response factor}}$$

In each computation it is important to apply the correct spectral response factor appropriate to the measurement step being conducted. When the indicated computation has been carried out, each phosphorescent standard will have one efficacy value. Fluorescent standards on the other hand will have both red and yellow channel values of efficacy. Some typical values for standards are:

Standard	Nominal PMU value	Typical value of efficacy	
Green phos.	22	0.0020	
Red phos.	22	0.0023	
Red fluor. - red	22	0.0030	(Temporary values with spectral response factor assumed equal 1.000)
" - yellow	22	0.0039	
Bkgnd fluor. - red (2 PMU)	2	0.0007	
" - yellow	2	0.0037	

2.2c(7) Conversion of efficacy to NBS-PMU values

The NBS-PMU value for phosphor standards is computed by multiplying the efficacy by a pre-determined constant. This constant has been established as the optimum conversion factor using a designated reference set of phosphor standards. From an intercomparison of the readings on the NBS instrument and on phosphormeters, the following conversion factors have been adopted:

Standard	Factor for Converting Efficacy to NBS-PMU	
Green phos.	10 583	
Red phos.	9 771	
Red fluor. - red channel	8 064	(Temporary values with spectral response factor assumed equal 1.000)
" - yellow channel	882	
Background fluor. - red channel	8 064	
" " - yellow channel	882	

When the conversions to NBS-PMU have been completed, all phosphorescent standards will have single values and fluorescent standards will have dual values, one for the red and one for the yellow channel. These values represent phosphor activity in the visible portion of the spectrum. However, because of phosphormeter design there are responses to other elements in the phosphor standards. These elements are not subject to precise calibration at present, but investigation has resulted in estimated corrections. The final step in the computation of working PMU values is applying these corrections.

2.2c(8) Computation of working PMU values

The working values for phosphor standards differ from the NBS-PMU values computed above by the correction indicated below. The resultant values are marked as NBS-PMU(T) on the standards.

Green phos. stds
NBS-PMU(T) = NBS-PMU +1.0

Red phos. stds
NBS-PMU(T) = NBS-PMU +8.0

Fluorescent stds (Red and Background)
NBS-PMU(T) = NBS-PMU (red channel) - NBS-PMU (yellow channel)

Each phosphor standard has been labeled with the NBS-PMU(T) value as the only item visible to the operator. However the components entering into this final step of conversion are given on the underlying label. If desired, they may be seen by removing the screws holding the metal name plate of the standard.

2.2d Electronics unit

The block diagram of the Electronics Unit is shown in Figure 13. The basic sections are:

1) Oscillator
2) Binary counter
3) Lamp drive
4) Sample delay
5) Sample period
6) Photomultiplier tube, PMT (located in Measurement unit)
7) PMT amplifier A_1
8) Integrator
9) Meter amplifier A_2
10) Digital voltmeter
11) Power supplies

Each of the above is described below in correspondingly numbered sections. Signal test points are listed in Figure 20. Locations of components are shown in Figures 21 and 22.

2.2d(1) Oscillator

The function of this circuit is to provide overall timing signals controlling the repetition rate and duty cycles of the measurement process. The circuit output is a pulse of 3.5 microseconds duration repeated 2000 times per second.

A circuit diagram is given in Figure 14. It is a relaxation oscillator whose period is controlled by the time constant (RC product) of C1 and R1 +R2. Adjustment of the exact frequency is accomplished through varying R1, as described in Section 2.2e. In the circuit of Figure 14, transistors Q1 and Q2 form the oscillator, with the output being amplified by Q3 to -5 volts. The output waveform is available on a test terminal at the rear of the chassis (TP1).

2.2d(2) <u>Binary counter</u>

The function of the binary counter is to provide the following outputs from the single input of pulses at 2000 hertz.

a) Lamp drive input, a 10-millisecond pulse at 0 volt repeated 10 times per second. Between pulses the output is +5 volts.

b) Sample delay pulses, switch selectable at 0, 9, 10 and 96 milliseconds delay from the leading edge of the lamp drive pulse above. The waveforms for 9, 10 and 96-ms delay go positive to +5 volts at the leading edge of the lamp drive pulse, and return to 0 volt at the designated delay time. For the 0-ms delay, a wave form which returns to 0 volt coincidentally with the leading edge of the lamp drive pulse is provided with its positive-going excursion at 36 milliseconds before then.

The binary counter is arranged for two counting ratios, 200X in the CHECK condition and 201X in the RUN. By synchronizing the oscillator frequency with the 60 hertz line power in CHECK and then operating off-synchronization, the effects of any spurious pickup of 60-hertz related signals can be averaged. For example, in the RUN condition the period is actually 100.5 milliseconds, hence each time of sampling luminescent signals occurs 0.5 millisecond later with respect to 60-hertz interference. This corresponds to a progressive phase delay of 0.5 ÷ 1/60 second x 360 degrees, or about 11° later after each passage of 6 complete cycles (60 cycles per second x 0.1 second). In approximately 3 seconds all possible phasings have been covered in one full cycle of 360 degrees. Thus if the signal averaging time is made long enough, the cancellation of hum pickup is relatively complete.

While the exact operating period of signal sampling is thus 0.1005 second instead of 0.1000 second, for all practical purposes the difference results in negligible effect upon the measured luminescent activity of phosphor standards. For simplicity of discussion, however, all timings are described in terms of the CHECK condition, where the period is set to precisely 0.1000 second.

The counter itself employs two type 7493 integrated circuits, each capable of counting to 16, or 256 for the pair in cascade. The circuit diagram is given in Figure 15. By suitable selection of the binary outputs to produce AND-gated reset signals, the total count is shortened to 200X or 201X for the CHECK and RUN conditions. Other AND gates generate the delayed timing signals at 0, 9, 10 and 96 milliseconds.

Charts of specific waveforms and other data too detailed for inclusion in this report are kept on file in the development laboratory. This information is available upon request at any time. Typical signals from the binary counter are noted in Figure 20 - Test point list.

2.2d(3) Lamp drive

This circuit provides the necessary on-off switching of current to the pulsed uv lamp. For the 10-millisecond, lamp-on interval during which the voltage of the input terminal is zero, a high voltage switching tube is turned on, drawing a current of approximately 10 milliamperes through the lamp. The equivalent circuit at this time is 580 volts in series with a resistance of 40,000 ohms. For the remaining 90 milliseconds of the cycle, the tube is turned off, so that the current through the lamp is then essentially zero.

The circuit diagram is shown in Figure 16, where the input transistor Q6 and the switch tube V1 can be seen. During the lamp-off time, the lamp drive input from the binary counter is +5 volts, causing Q6 to be fully conducting. This holds the control grid of V1 at zero volt. Since the cathode of V1 is at +20 volts, with the screen grid at +50 volts, V1 is cut off, so that no current flows through the lamp.

When the input transistor Q6 is cut off by lowering the lamp drive signal to zero input voltage, the control grid of V1 rises until the grid attempts to become positive with respect to the cathode, by virtue of the current of approximately 0.15 milliampere flowing through R19. Most of the 3 milliamperes through R23 and R24 flows in the screen grid circuit, causing the screen voltage to drop to about 7 volts above the cathode. During this conducting period the plate voltage is very close to that of the cathode, bringing the switched side of the lamp to approximately +25 volts. At the high side of the lamp there is a combination of zener diodes, amounting to 400 volts drop, in series with 40 000-ohm resistance. The parameters in the circuit are chosen to provide reliable lamp starting, through application of a pulse of sufficiently high voltage with a resistive ballast capable of damping any tendencies toward oscillation in the lamp.

Associated with the uv pulsed lamp is a keep-alive lamp whose purpose is to assist further in reliable firing of the main lamp. Current through this keep-alive lamp is approximately 0.18 milliampere, as determined by a resistance of 4.7 megohm in series with the 1000-volt power supply.

2.2d(4) Sample delay

This circuit provides additional time delay which is added to the digitally-derived delay period (0,9,10 or 96 milliseconds) from the binary counter. Two ranges are provided, allowing the addition of up to 11.0 ms in steps of 0.1 millisecond. The output signal is a voltage which goes to +5 volts when the input trigger, as selected by the right hand dial of the SAMPLE DELAY switch, drops from +5 to 0 volts. At the end of the additional delay period, the output of the sample delay circuit drops from +5 to 0, triggering the onset of the Sample Period circuit which follows. The total combination of delay periods allows wide freedom in selecting the time of signal measurement, all measured from the time the pulsed uv lamp is turned on.

A diagram is given in Figure 17. The duration of the sample delay period is controlled by the RC product of R11 and C6 through C13. These circuit elements are external to the time delay generator type 74121 integrated circuit module. Additional capacitance may be added at this point, increasing the sample delay by approximately 10 milliseconds per microfarad.

Waveforms for checking input and output are available at TP3 and TP4 respectively.

2.2d(5) Sample period

This circuit sets the time duration of the gating period during which the PMT output signal is accepted for metering. It is normally set for 50 microseconds. The output is at approximately -13 volts when not sampling, rising to +15 volts for 50 microseconds during the sample period.

The diagram is included in Figure 17. The circuit uses the type 74121 delay generator with external resistance and capacitance R16 and C14, set for 50 microseconds. An inverting amplifier stage Q4 is employed at the output to supply the relatively high level required by the following FET switch. Waveforms for input and output are available at TP4 and TP5 respectively.

2.2d(6) Photomultiplier tube (PMT)

The function of the PMT is to convert incident uv and visible energy reflected or emitted from the standards to electrical current at the tube's anode terminal. Normal maximum output current is 10 microamperes.

The circuit diagram is given in Figure 18. The photomultiplier tube has a 2-inch (50.8 mm) diameter, flat-faced, end window with a 44 millimeter cathode and 11 dynodes of the venetian blind type having cesium antimony secondary emitting surfaces. The cathode is of the S-20 or tri-alkali type, with a spectrosil (fused silica) window. The PMT type designation is 9558QMA.

The housing and shield protecting the PMT also contains the socket-mounted voltage divider. The dynode voltage increments in this divider are uniform, including the anode to the last dynode. Cathode to first dynode voltage,however,is fixed by a zener diode at 150 volts so that the variation in sensitivity across the cathode is not changed when the overall PMT gain is increased or decreased.

2.2d(7) PMT amplifier A1

The function of the PMT amplifier is to provide a high-level, low-impedance, signal voltage which is proportional to the PMT current. The output voltage range is from zero to +10 volts, corresponding to a maximum PMT current of 10 microamperes.

The circuit diagram is included in Figure 18, where the basic element, an operational amplifier is shown. Feedback is through a one-megohm resistor (R12), in parallel with a capacitance of 22 picofarad (C4). Together these set the high frequency cutoff to 7 000 hertz in order to minimize noise response for pulse amplitude measurements. When the Detector Calibrator is used, it is necessary to average or smooth out the 120-hertz ripple from the stabilized lamp. Therefore in the CONTINUOUS position of the METER sw, a large capacitor (0.22 microfarad) is added in shunt with the feedback resistor. This lowers the amplifier bandwidth to 0.7 hertz.

2.2d(8) Integrator

The function of the integrator is to accept the luminescent signal from the PMT amplifier during the sample period and to store or smooth out the signal to provide a stable indication of PMT output. It can also be regarded as a combination of pulse-stretching and low-pass filtering circuits.

The diagram of Figure 18 shows the circuit, with its two major elements, the FET switch and the integrating capacitor. During the 50-microsecond sample period the FET switch Q5 becomes a low impedance between its source and drain terminals, in effect connecting the output of the PMT amplifier to the 0.5 microfarad storage capacitor C5. A resistance of 1600 ohms (R15) is inserted in series with the FET switch to limit the peak current and to assure that the charging and discharging rates are nearly similar. Between the sampling periods, the gate of the FET switch is held negative at approximately -13 volts resulting in cutting off the FET switch, so that the capacitor is then disconnected from the input. Thus the storage capacitor is connected to the PMT signal for a 50-microsecond sample period at a repetition rate of 10 times per second. During the sample period the capacitor charges or discharges toward the signal amplitude. This charge or discharge is only partial, since the time constant of R15 and C5 is long, approximately 900 microseconds. When a step function of input PMT signal is applied, as by opening or closing the shutter slides, the capacitor voltage rises or falls with a time constant of approximately 1.8 seconds. The lengthening of the effective time constant by a factor of 2000 ($1.8 \div 900 \times 10^{-6}$) is due to the duty cycle of the sample period ($50 \div 100\,000$ microseconds or 1/2000).

No test point is provided for the direct output of the storage capacitor, since any resistive loading would cause a change in stored PMT signals. Full scale signal at the capacitor is +10 volts.

2.2d(9) Meter amplifier A2

This circuit provides isolation of the PMT signal voltage as stored on the capacitor C5.

The diagram of Figure 18 shows the circuit configuration, which is an operational amplifier connected as a voltage follower having high-impedance input. At its output (TP8) the integrated and stored PMT signals from C5 may be observed. Full scale is +10 volts. This point is also the source of signals displayed on the panel Oscilloscope.

2.2d(10) Digital voltmeter

This is 3-1/2 digit voltmeter having one millivolt resolution up to 2.000 volts maximum. In order to accommodate the 10 volt signal range at the output of amplifier A_2, a 5:1 divider (R14 and R16) is employed at the input of the digital voltmeter. If for some reason increased sensitivity of the voltmeter by a factor of 5 is desired, the input resistor R14 may be short-circuited.

2.2d(11) Power supplies

The group of power supplies in the Electronics unit deliver regulated power for the purposes indicated below.

Voltage	Current	Use
+15 VDC	50 mA	Amplifiers A1,A2
+5 VDC	-	Binary counter
-15 VDC	50 mA	Amplifiers A1,A2
0 to 2000 VDC	10 mA	PMT
0 to 1000 VDC	20 mA	Pulsed uv lamp

Supplies delivering unregulated outputs are:

Voltage	Current	Use
+8 VDC	500 mA	Heater for pulsed uv lamp
-6 VDC	100 mA	Heater for pulsed uv lamp

The wiring diagram for these supplies and their control switches is given in Figure 19.

2.2e Adjustment of controls in Electronic unit

There are four screw driver-operated controls which must be adjusted according to specifications for proper operation of the equipment. The adjustment procedures are covered individually in the appropriate paragraphs below.

2.2e(1) Frequency trim

With the equipment turned on normally and warmed up for at least 30 minutes:

1) Close the PULSED LAMP shutter by raising the slide

2) Set METER SW to PULSED

3) Remove any standard from sample holder, turn on room lights.

4) Set SYNC switch to CHECK

5) Increase the sensitivity on the OSCILLOSCOPE until a pattern with 120-hertz ripple can be seen.

6) Adjust the FREQ TRIM control with a screwdriver until the pattern is stable with respect to the bright trace dot. Stable is defined as not more than 2 milliseconds drift in 5 seconds time. If necessary adjust the intensity of the oscilloscope beam to make the dot readily visible.

2.2e(2) Delay trim

With the equipment turned on and warmed up for 30 minutes:

1) Close the PMU shutter by raising the slide.

2) Set the left and center SAMPLE DELAY to zero, and the right hand dial to 10 ms delay. Set the oscilloscope sweep rate to one millisecond per centimeter. Note the horizontal position of the bright dot on the trace.

3) Set the left dial to 10 ms, and the center and right dials to zero. The horizontal position of the bright dot should be set with the DELAY TRIM adjustment so that it coincides within 100 microseconds of the position found in (2) above.

2.2e(3) Zero adjust

With the equipment turned on and warmed up for at least 20 minutes:

1) Close the PMT shutter by raising the slide.

2) Turn the Zero Adjust control for an indication on the Panel Meter which causes the polarity display to swing between negative and positive. The digits will be 000 in this condition.

As a check during operation, the indication should always return to either +000 or -000 whenever the PMT shutter is closed. It is not necessary to readjust the control unless the indication is more than 001 (negative or positive).

2.2e(4) Sample period

With the equipment turned on and warmed up for 30 minutes:

1) Close the PMT shutter by raising the slide

2) Set all three SAMPLE DELAY dials to zero

3) Adjust the SAMPLE PERIOD control so that the bright portion of the trace has a duration of 50 $\pm$ 2 microseconds as indicated on the oscilloscope. It may be necessary to reduce the intensity setting of the beam in order to observe the bright portion clearly.

3.0 Operating procedure, Comparator mode

Operation in the Comparator mode produces indications of relative phosphorescent or fluorescent activity, permitting the comparative evaluation of phosphor standards of similar type. Quantitative evaluations of unknown phosphor standards can be performed to the extent that applicable reference standards of known values are available.

In the operating procedures which are listed below, a uniform settling time of 30 seconds should be allowed before readings for standards are taken.

3.1 Comparator mode, phosphorescent standards

1) The first step in the operating procedure is to turn on the instrument and wait for warm-up. The relevant controls can be seen in Figure 12, and should be turned on in the following order:

   OSCILLOSCOPE
   HEATER power
   CIRCUIT power
   PULSED LAMP power supply
   PMT power supply

2) Allow 15 to 30 minutes for warm-up. During this time the following control settings should be made or checked.

Control	Setting
METER SW	set to PULSED
SYNC	" " RUN
SAMPLE DELAY	" " 0 on left dial " " 0.5 on center dial " " 10 on right dial
PULSED LAMP supply	" " 1000 volts
DET. CAL power supply	OFF

3) In the Measurement Unit, shown in Figure 4, the following control positions should be or set or verified

-Comparator mode-phosphorescent standards-

Control	Setting
PULSED LAMP shutter slide	down position (open)
PMT " "	up (closed)
DET CAL " "	up (closed)
FRONT FILTER handle	down (uv-pass, attenuator)
REAR FILTER handle	down (open)
MASK	Phosphorescent mask in place (one notch at upper right)

The operating procedure requires the following steps:

4) Remove top cover of filter case and REAR FILTER carriage; then remove any filters and reinsert the carriage.

5) Lift both FILTER handles by releasing the mechanical stop at the left side. Set to the up position, for the visible-pass condition.

6) Insert reference standard into sample holder and turn handle up. This handle must always be down when a standard is being inserted, and up for measurement.

7) Open PMT shutter completely by moving slide down to where the handle touches the base.

   At this point there should be a rise-and-decay pulse visible on the OSICLLOSCOPE, as well as a reading on the DIGITAL METER. Verify that the right hand switch on the SAMPLE DELAY is in position 10 by noting that the bright dot in the trace comes near the start of the phosphor decay.

8) Adjust the PMT voltage control by turning the thumbwheel switches so that the PMT output is less than 10 volts, and that the digital panel meter (DPM) is less than 2.000 volts. It is desirable to use the highest PMT voltage that will not produce overload on the DPM for the highest-valued phosphor standard in the group to be compared.

9) With the reference phosphorescent standard in place, record the indicated output voltage, allowing approximately 30 seconds for settling time.

10) Replace the reference standard with others to be measured, noting the output on each standard.

11) Reinsert the reference standard and remeasure for indication of any drift which might result from warm-up of the pulsed lamp or PMT.

12) Measure the apparent phosphorescent activity of Standard N2, which will be very low, since instrument response to the zero phosphor standards is very small.

13) Subtract the output of N2 from all other readings to correct for the small response to the ceramic wafer base.

14) Compute the relative phosphorescent activity of each tested standard with respect to the reference, then compute new NBS-PMU values by multiplying the relative activity by the known value of the reference. It is the visible phosphorescent activity (NBS-PMU) of the reference standard which must be used in the computation.

    If drift is evident from a difference in the observed beginning and ending values on the reference standard, interpolate on the basis of the time of measurement to find the best value of the reference which is applicable to each measurement on test standards.

15) Compute the new working value by adding the correction for phosphormeter response to the ceramic wafer base. Add 1.0 PMU to green phosphor standards and 8.0 to red. Remove the old label and replace with a new one with the new NBS-PMU(T) values. Log and plot the new data on the appropriate forms.

16) Turn off the equipment when work is completed, using the reverse of the order indicated in step (1).

3.2 Comparator mode, fluorescent standards

Fluorescent standards can be evaluated in the Comparator mode, provided reference standards are available whose separate red and yellow channel activities have been previously evaluated. It is recommended that Red Fluorescent and Background or Balance Adjust standards respectively be employed for this purpose. The normal stamped or calibrated rating of these standards is based upon subtracting a fraction of the yellow fluorescence from the red. The actual red channel activity is typically 10 to 20 percent higher than the calibrated rating of red fluorescent standards. Yellow channel activity differs even more from the stamped ratings on background or balance adjust standards. The actual yellow channel activity may be as high as 10 to 20 PMU on standards whose stamped ratings are 1 to 2 PMU.

For convenience the entire operating procedure is listed below, however certain descriptions have been condensed on the assumption of familiarity with the steps in 3.1 above.

1) Turn on the instrument switches in the following order, the same order as indicated previously.

    OSCILLOSCOPE
    HEATER power
    CIRCUIT power
    PULSED LAMP power supply
    PMT power supply

2) Allow 15 to 30 minutes for warmup, making or checking the following control settings:

Control	Setting
METER SW.	set to PULSED
SYNC	set to RUN
SAMPLE DELAY	set to 0 on left dial " "0.5 on center dial " " 9 on right dial
PULSED LAMP power supply	set to 1000 volts

3) In the Measurement unit, set or verify the following positions:

Control	Setting
PULSED LAMP shutter slide	down position (open)
PMT shutter slide	up (closed)
DET. CAL. shutter slide	up (closed)
FRONT FILTER handle	down (uv-pass, attenuated)
REAR FILTER handle	down (open)
MASK	Fluorescent mask (two notches) at upper right

The operating procedure requires the following steps:

4) Remove REAR FILTER carriage, insert the red channel F1 filter into the VIS. position, with the engraved lettering at top, facing the sample holder. Reinsert carriage into filter case and replace cover.

5) Lift both FILTER handles to the up position, for the visible-pass condition.

6) Insert reference standard into sample holder and turn handle up.

7) Open PMT shutter by moving slide down.
Signal and readings should be visible on panel. Verify that SAMPLE DELAY is at 9.5 milliseconds total, with the trace dot coming during the uv pulse, near the end.

8) Adjust PMT voltage for high-level signal without overload on highest standard to be tested.

9) With the reference fluorescent standard in place record the indicated output voltage.

10) Replace the reference standard with others to be measured, noting the output from each.

11) Reinsert the reference standard and remeasure for drift indication.

12) Measure the zero phosphor standard N2.

13) Multiply the output from N2 by 1.5 and subtract it from all other output readings. Note that this multiplying factor is required only for fluorescent standards where the wafer size is 50 per cent larger.

14) Compute the relative fluorescent activity of each tested standard with respect to the reference, then scale appropriately to find NBS-PMU values. Observe caution that appropriate red and yellow channel reference evaluations are used in the computations. Take observed drift, if present, into account by interpolation.

15) For fluorescent standards it is necessary to measure and compute the NBS-PMU value for both red and yellow channels. It is therefore necessary to perform the above procedure with the red F1 filter and then repeat it with the yellow B1 filter. Therefore it is necessary to go back to step (4) closing the PMT shutter before replacing the filter.

16) Compute working values by subtracting the results of the yellow channel readings in PMU from those of red channel measurements. Label the phosphor standards with the new NBS-PMU (T) values, removing old labels as needed. Log and plot the new data on the appropriate forms.

17) Turn off the equipment when work is completed, using the reverse of the turn-on procedure.

4.0 Operating procedure, Calibrator mode

This mode of operation results in evaluations of phosphor standards without direct comparison with known reference standards. It can be used to monitor the behavior of standards, including reference standards, over an extended period of time. In the Calibrator mode, evaluation of phosphor standards is referred to measurements of the relative spectral irradiance from a standard tungsten-halogen lamp in the ultraviolet and visible spectral regions. The procedure is identical for green and red phosphorescent standards except that the computations require different values of parameters.

When operating in the Calibrator mode, there is considerable detail work which must be performed regardless of the number of standards to be measured. Hence it will be found desirable to measure phosphor standards in batches. It is also recommended that reference standards be included in the measured group whenever possible, to provide data on standards and system performance.

4.1 Calibrator mode, phosphorescent standards

The detailed procedure is described below. While familiarity with the operation as outlined previously is assumed, all of the necessary steps are listed. Sample data sheets are shown in Figure 23.
The operating procedure begins with turning on the equipment in the order given and waiting for warm-up.

1) Turn on OSCILLOSCOPE
   " " HEATER power
   " " CIRCUIT power
   " " PULSED LAMP power supply
   " " PMT power supply

2) Allow 15 to 30 minutes for warm-up. Make or check the following control settings:

Control	Setting
METER SW	set to PULSED
SYNC	" " RUN
SAMPLE DELAY	" " 0 on left dial " " 0.5 on center dial " " 0 on right dial
PULSED LAMP supply	" " 1000 volts
DET. CAL. power supply	" " ON

3) In the Measurement Unit, set or check the following control positions:

Control	Setting
PULSED LAMP shutter slide	down position (open)
PMT " "	up (closed)
DET. CAL. " "	up (closed)
FRONT FILTER handle	down (uv-pass, attenuator)
MASK	Phosphorescent mask in place (one notch at upper right)

4) Take off cover of filter case, remove REAR FILTER carriage, remove any filter(s), reinsert carriage and replace cover. Put both FILTER handles in down position.

5) Open PMT shutter by moving handle down

6) Insert barium sulfate reflectance standard in sample holder

7) At this point a pulse signal should be visible on the OSCILLOSCOPE as well as a reading on the DIGITAL METER. The bright dot in the trace should be at the top and near the start of the visible pulse.

8) Adjust the PMT supply voltage to produce an indication of approximately 1.700 on the panel meter.

9) Record the indicated PMT output for this time sample (0.5 millisecond). Note also the time of day at which the observation was made.

10) Advance the sample delay to 1.5 milliseconds by turning the left hand control to 1 millisecond. Record the output for this sample delay.

11) Advance the left hand control in sample delay to the next position (2 milliseconds), recording the observed indication. Repeat this procedure until the last sample at 9.5 milliseconds has been recorded. Then note the time of the observation. This completes the measurements necessary to determine the effective uv pulse as reflected from the barium sulfate standard.

12) Remove the reflectance standard and insert the phosphorescent standard to be tested.

13) Lift both FRONT and REAR FILTER handles to the up, or visible-pass, condition.

14) Set the center and right controls in SAMPLE DELAY to a total of 10.5 milliseconds. Set the left control to zero.

15) Record the indicated output for the tested standard, noting also the time of day for the first standard.

16) Repeat for other standards in the test group. Usually it will only be necessary to note the time for the first and last standards in a group. It is recommended that several reference standards also be included in the test group.

17) Measure also the Zero Phosphor standard N2 or its designated equivalent.

18) Go back to step (4) and repeat throguh step (11) in order to measure the uv pulse amplitude. When a large number of standards is to be calibrated (five or more) this measurement of the uv pulse should be performed every 15 or 20 minutes, unless experience shows negligible drift. Do not change PMT supply voltage during these measurements involving the phosphor ratios.

At this point the data have been taken from which the Phosphor ratios can be determined. The next phase is to measure the Detector ratio.

19) In the Measurement unit, set or check the controls as follows:

Control	Setting
PULSED LAMP shutter slide	set to up (closed)
PMT " "	" " up (closed)
DET. CAL. " "	" " up (closed)
FRONT FILTER handle	" " up (visible-pass)
REAR FILTER handle	" " up

20) In the Electronics unit:

METER SW	set to CONTINUOUS

21) In the Detecotr Calibrator Unit, set or check:

LAMP POSITION	pointer at 90 cm on scale

-Calibrator mode-phosphorescent standards-

22) Insert DET. CAL. FILTER marked 546 nm (221.12) into holder in Detector Calibrator, to pass only 546 nm line from the internal calibrated lamp. Make sure that filter is located in rear of holder, as far toward the lamp as it will go.

23) Insert barium sulfate reflectance standard No. 27 into sample holder.

24) Open DET. CAL. and PMT shutters by moving slides down to base.

25) Observe indications on DIGITAL METER. Increase PMT voltage if necessary to bring reading to approximately 1.800 ± 0.100 volts.

26) Record PMT output for 546 nm radiance from the Detector Calibrator.

27) Close DET. CAL. shutter by raising slide, change DET. CAL. FILTER to uv-pass element designated 254 nm (411.04), open DET. CAL. shutter.

28) Lower both FRONT and REAR Filter handles, for uv-pass conditions.

29) Record PMT output for 254 nm radiance from Detector Calibrator.

This completes the measurement phases involved in the calibration of phosphor standards. Turn off the DET. CAL. power supply to conserve lamp life.

The next phase is the computation of efficacy, the visible phosphorescent activity of the tested standards.

30) Subtract the measured value for the ZERO phosphor standard N2 from all readings of phosphorescent activity derived in steps (15) and (16).

31) Compute the effective uv pulse amplitude by multiplying the measured values from steps (9) through (11) by the following constants,

-Calibrator mode-phosphorescent standards-

Delay time milliseconds	Multiplier for green stds.	Multiplier for red stds.
0.5	0.11	0.54
1.5	.13	.56
2.5	.15	.58
3.5	.18	.61
4.5	.22	.65
5.5	.26	.68
6.5	.33	.72
7.5	.42	.76
8.5	.56	.82
9.5	.81	.90
Divide the sum of weighted products by	3.17	6.82

Perform this computation for the effective uv pulse amplitude as applicable to green and red. If an observable drift is evident (more than 0.5 percent) interpolate to determine appropriate values to be assigned to the measurements of phosphorescent activity in steps (15) and (16).

32) Compute Phosphor ratios for all tested standards, dividing the results of step (30), phosphorescent emission, by those from (31), weighted uv excitation.

33) Compute the Detector ratio by dividing the results of step (29), response to uv from Detector Calibrator, by (26) response to visible light from Det. Cal.

34) Compute Efficacy as the product of:

$$\text{Efficacy} = \frac{(\text{Phos.ratio})(\text{Det.ratio})(0.1570)(0.976)}{(1.004)}$$

for green phosphorescent standards, and

$$\text{Efficacy} = \frac{(\text{Phos.ratio})(\text{Det.ratio})(0.1570)(0.976)}{(0.641)}$$

for red phosphorescent standards

35) Compute NBS-PMU with the following conversion constants:

NBS-PMU = Efficacy x 10 583 for green phos. stds.

" = " 9 771 " red " "

36) Compute working USPS PMU values by adding 1.0 to the above for green standards, and 8.0 for red. Label the phosphor standards with the NBS-PMU(T) values and the date in month and year, removing old labels as needed. Log and plot the new data on the appropriate forms.

37) Turn off the equipment in the reverse of the order indicated in step (1).

4.2 Calibrator mode, fluorescent standards

The operating procedure begins with turning on the equipment in the order given and waiting for warm-up.

1) Turn on OSCILLOSCOPE
   " HEATER power
   " CIRCUIT power
   " PULSED LAMP power supply
   " PMT power supply

2) Allow 15 to 30 minutes for warm-up. Make or check the following control settings:

Control		Setting
METER SW	set to	PULSED
SYNC	"	RUN
SAMPLE DELAY	"	0 on left dial
	"	0.5 on center daal
	"	9 on right dial
PULSED LAMP supply	"	1000 volts
DET CAL power supply	"	ON

3) In the Measurement unit, set or check the following control positions:

PULSED LAMP	shutter	slide	down position (open)
PMT	"	"	up (closed)
DET CAL	"	"	up (closed)
FRONT FILTER handle			down (uv-pass, attenuator) (two notches at upper right)

4) Remove REAR FILTER carriage, insert the red channel F1 filter into the VIS position, with engraved lettering at top, facing the sample holder. Reinsert carriage and replace cover. Lower both FILTER handles.

5) Open PMT shutter by moving handle down.

6) Insert barium sulfate reflectance standard in sample holder.

7) A pulse signal should be visible on the OSCILLOSCOPE as well as a reading on the DIGITAL METER. Verify that the bright dot in the trace is at the top of the pulse, near its end.

8) Adjust PMT supply voltage control to produce an indication of approximately 1.700 on the panel meter.

9) Record the PMT output. Note also the time of the observation.

10) Raise both FILTER handles to the visible-pass condition.

11) Remove barium sulfate standard, replacing with those to be measured, noting the output from each in the appropriate log form. It is desirable to include one of the reference red fluorescent standards with the group to be measured.

12) Measure also the Zero Phosphor standard N2 or its designated equivalent.

13) Remeasure the uv pulse amplitude by going back to steps (6) (7) and (9). It will first be necessary to lower the FILTER handles to the uv-pass, attenuator, condition.

At this time the data have been taken from which Phosphor ratios for the red channel can be determined. The next phase is to measure Phosphor ratios for the yellow channel on the same standards.

14) Go back to step (4) and replace with the yellow channel filter B1, first closing the PMT shutter slide. If more than 15 minutes have elapsed since the last reading of uv pulse in step (13), repeat the uv pulse measurement indicated in steps (6) (7) and (9) before beginning the series of tested standards. Do not change PMT supply storage.

15) Repeat the measurement steps (10) through (12) with the yellow channel filter in the PMT filter case.

16) Repeat step (13) to produce the final uv pulse amplitude, then continue below.

All data have now been taken for the Phosphor ratios in both the red and the yellow channels. The next phase is to measure the Detector ratio.

17) Close the PMT shutter slide by moving it up.

18) Remove the REAR FILTER carriage and extract the filter. Reinsert carriage and replace cover.

19) In the Measurement unit, set or check the controls as follows:

PULSED LAMP shutter slide			set to up (closed)
PMT	"	"	" up (closed)
DET CAL	"	"	" up (closed)
FRONT FILTER handle			" up (visible pass)
REAR FILTER	"		" up

20) In the Electronics unit:

METER SW	set to CONTINUOUS

21) In the Detector Calibrator unit, set or check

LAMP POSITION	pointer at 90 cm on scale

22) Insert DET CAL FILTER marked 546 nm (221.12) into holder in Detector Calibrator, to pass only 546 nm line from the internal calibrated lamp. Make sure that the filter is in the rear end of the holder, as far toward the lamp as possible.

23) Insert barium sulfate reflectance standard F7 into sample holder.

24) Open DET CAL and PMT shutters by moving the slides down to the base.

25) Observe indications on DIGITAL METER. Increase PMT voltage as required to bring reading to approximately 1.800 ±0.100 volts.

-Calibrator mode-fluorescent standards-

26) Record PMT output for 546 nm radiance from the Detector Calibrator.

27) Close DET CAL shutter by raising slide, change DET CAL FILTER to uv-pass element designated 254 nm (411.04), then open DET CAL shutter.

28) Lower both FRONT and REAR FILTER handles, for uv-pass condition.

29) Record PMT output for 254 nm radiance from Detector Calibrator.

This completes the measurement phases required in the calibration of fluorescent phosphor standards. Turn off the DET CAL power supply to conserve lamp life. The next phase is the computation of efficacy in the red and yellow channels.

30) Multiply the measured value for the Zero phosphor standard N2 by 1.5 and subtract from readings of red-channel activity for all tested standards. Do the same for the yellow channel outputs, using the measured value of the yellow-channel for the N2 standard.

31) Determine the effective uv pulse amplitude applicable to each tested standard, interpolating according to time of measurement if observed drift is more than 0.5 percent between initial and final values.

33) Compute Phosphor ratios for all tested standards, dividing the results of step (30) fluorescent emission, by those from (31), uv excitation.

33) Compute the Detector ratio by dividing the results of step (29), response to uv from Detector Calibrator, by step (26), response to visible light from Det. Cal.

34) Compute efficacy separately for each tested standard in the red and yellow channels as the product of:

$$\text{Efficacy} = \frac{(\text{Phos. ratio})(\text{Det. ratio})(0.1570)(0.948)}{(1.000)}$$

35) Compute NBS-PMU separately for red and yellow channels as:

NBS-PMU = Efficacy x 8506 for red channel

" " x 930 " yellow "

36) Compute working PMU values by subtracting the yellow from the red channel values of NBS-PMU:

NBS-PMU(T) = NBS-PMU (red channel) - NBS-PMU (yellow channel)

Remove old labels.
Label fluorescent standards with the NBS-PMU(T) values and the date in month and year. Log and plot the new data on the appropriate forms.

37) Turn off the equipment in the reverse of the order indicated in step (1).

5.0 Components

5.1 Five-year spare parts list

Certain of the components given the complete list in Section 5.2 are considered necessary for a five year maintenance program. These are identified in the list of five-year spare parts below, and have been set aside for contingency.

Item	Quantity used	Quantity retained as spares
Transistors		
2N2219	1	1
2N3638	1	1
2N3643	3	2
2N4222	1	1
Integrated circuits		
7400	2	1
7421	1	1
74121	2	1
7493	2	1
Operational amplifiers		
40J	2	1
Voltage regulator		
MA7805	1	1
Vacuum tube		
5CD6	1	1
Diodes		
1N4005	1	1
1N4747	1	1
1N4751	1	1
1N4764	4	1
Pulsed uv lamp	2	3

The remaining components are in common use and aside from the complete units, are available from the NBS or other electronic storerooms.

5.2 Complete parts list

The following is a list of the parts in the Electronic unit. In keeping with the policy prohibiting the use of proprietary names in agency reports, insofar as possible the components are described in terms of technical characteristics. For the few cases in which this is not feasible the descriptions are supplemented by a separate list of manufacturers.

Resistors

R1	10 000	ohms, 5% tol., 1/4 watt
R2	8 100	" " "
R3	2 200	" " "
R4	2 200	" " "
R5	22 000	" " "
R6	2 200	" " "
R7	100 000	" " "
R8	220 000	" " "
R9	10 000	" " "
R10	470	" " "
R11	2 500	ohms, potentiometer, linear taper
R12	1.0	megohm 5% tol., 1/4 watt
R13	100 000	ohms 5% tol., 1/4 watt
R14	30 000	" " "
R15	1 600	" " "
R16	25 000	" potentiometer, linear taper
R17	500	" 5% tol., 1/4 watt
R18	13 000	" " "
R19	51 000	" 10% Tol., 5 watts
R20	40 000	" " "
R21	1.0	megohm, 10% tol., 1/2 watt
R22	1.0	" " "
R23	150 000	ohms " 2 watt
R24	150 000	" " "
R25	4.7	megohms " "
R26	200 000	ohms 5% tol., 1/4 watt
R27	200 000	" " "
R28	20 000	" 1% tol., 1 watt (wire wound)
R29	5 000	" " " "

Capacitors

C1	0.0068 microfarad
C2	0.002 "
C3	0.002 "
C4	22 picofarad
C5	0.5 microfarad (polystyrene)

Capacitors

C6	0.1 microfarad,	5% tol.,	200V	
C7	0.2 "	"	"	
C8	0.3 "	"	"	(0.1 + 0.2 in shunt)
C9	0.4 "	"	"	(0.2 + 0.2 in shunt)
C10	0.01 "	"	"	
C11	0.02 "	"	"	
C12	0.03 "	"	"	
C13	0.04 "	"	"	
C14	0.0069 "	10%	"	
C15	0.1 "	20%	50V	
C16	50 "	-	15V	(electrolytic)
C17	50 "	-	15V	"
C18	2000 "	-	15V	"

Transistors

Q1	2N 3638
Q2	2N 3643
Q3	2N 3643
Q4	2N 3643
Q5	QN 4222 (FET)
Q6	QN 2219

Integrated circuits

U1	7493	4-bit Binary counter
U2	7493	" " "
U3	7400	Quad 2-Input Gate
U4	7400	" " "
U5	7421	Dual 4-Input Gate
U6	74121	Monostable multivibrator
U7	74121	" "

Operational amplifiers

A1,A2	Type 40J, FET input, 10V at 5 mA output 4 MHz bandwidth, high input impedance

Voltage regulator

VR1	MA7805, 5V, 500 mA

Tube

V1	6CD6 Beam power amplifier

Diodes

D1	1N4005	
D2	1N4764	100V, 10% tol. 1 watt, Zener
D3	"	" " " "
D4	"	" " " "
D5	"	" " " "
D6	1N4747	20V " " "
D7	1N4751	30V " " "
D8	1N4005	
D9	"	
DB1	MDA 920A-7 diode bridge, 1A	

Lamps

N1	NE 51 neon lamp
N2	" " "

Transformers

T1	RT-202 18 VAC, center-tapped, 1.0A or greater
T2	T-21 6.3 VAC, center-tapped, 1.0A or greater

Complete units

Digital Voltmeter	0 to 1.999 VDC in steps of one millivolt, input impedance greater than 1 G
Power Supplies ± 15 VDC	± 15 VDC at 50 mA, 0.1% regulation
2000 VDC	0 to 200 VDC at 10 mA, 0.05% regulation
1000 VDC	0 to 1000 VDC at 20 mA, 0.1% regulation
Oscilloscope	5 inch dia. CRT, freq. response 0 to 500 kHz, z-axis modulation, panel mounted
Stabilized uv lamp	Stabilized low pressure mercury vapor source 254 nm primary emission, with regulated power supply and temperature-controlled lamp chamber
Pulsed uv lamp	Type SPR-33, low pressure mercury vapor source in quartz envelope, diameter approximately 0.25 inch, length 2 inches (6.3 x 51 mm)

Photomultiplier tube	Type 9558 QMA, with 2-inch (51 mm) diameter, flat faced, end window of fused silica. Cathode diameter 4.4 mm, S20 or tri-alkali type. Eleven-stage, venetian-blind electron multiplier of cesium antimony surfaces. Mounted in magnetic shield including socket and voltage divider.

Manufacturers' data sheets and instruction manuals as applicable have been assembled in a file for retention along with the five-year spare parts.

5.3 List of Mechanical Drawings (in separate package)

Phosphor Standard Calibrator

No.	Drawing
1	Overall Layout (not a working drawing)
2	Base and Top
3	Cover, Sides, Front
4	Baffles, Universal, & Parts
5	Front Baffle
6	PC Baffle
7	Sides of Filter Holder
8	Filter Carrier, Parts
9	Latch for Filter Handle
10	Front, Back for Filter Holder
11	Body for Dark Slide
12	Dark Slide
13	Mount for UV Lamp
14	Dark Slide for Lamp
15	Housing for UV Lamp, Parts
16	Back Plate, Lever for Sample Holder
17	Front Plate, Mask for Sample Holder
18	Base Plate, Spacers
19	Dark Slide for Calibrator
20	Filter Shield (not used)
21	Parts for PMT Mount
22	Baffle Plates
23	UV Filter Holder
24	Parts for Light Shielding
25	Light Shield for Sample Holder
26	Flat Sample Holder
27	Sketches, Detector Calibrator
28	Bottom, Upper Plate, Det. Cal.
29	Sides and Ends, Det. Calibrator
30	Brace
31	Assembly of Tunnel Section, Det. Cal.
32	Overall Base
33	Small Tunnel for Detector Calibrator
34	Cover Plates for Det. Cal.
35	Baffle Plates for Det. Cal.
36	Parts for Lamp Cradle
37	Cover Plate, Etc. for Det. Cal.
38	Label Parts for Phosphor Standards
39	Cover, Parts, for UV Lamp
40	Filter Holder, Handle
41	Scale for Detector Calibrator
42	Baffles for Small Tunnel

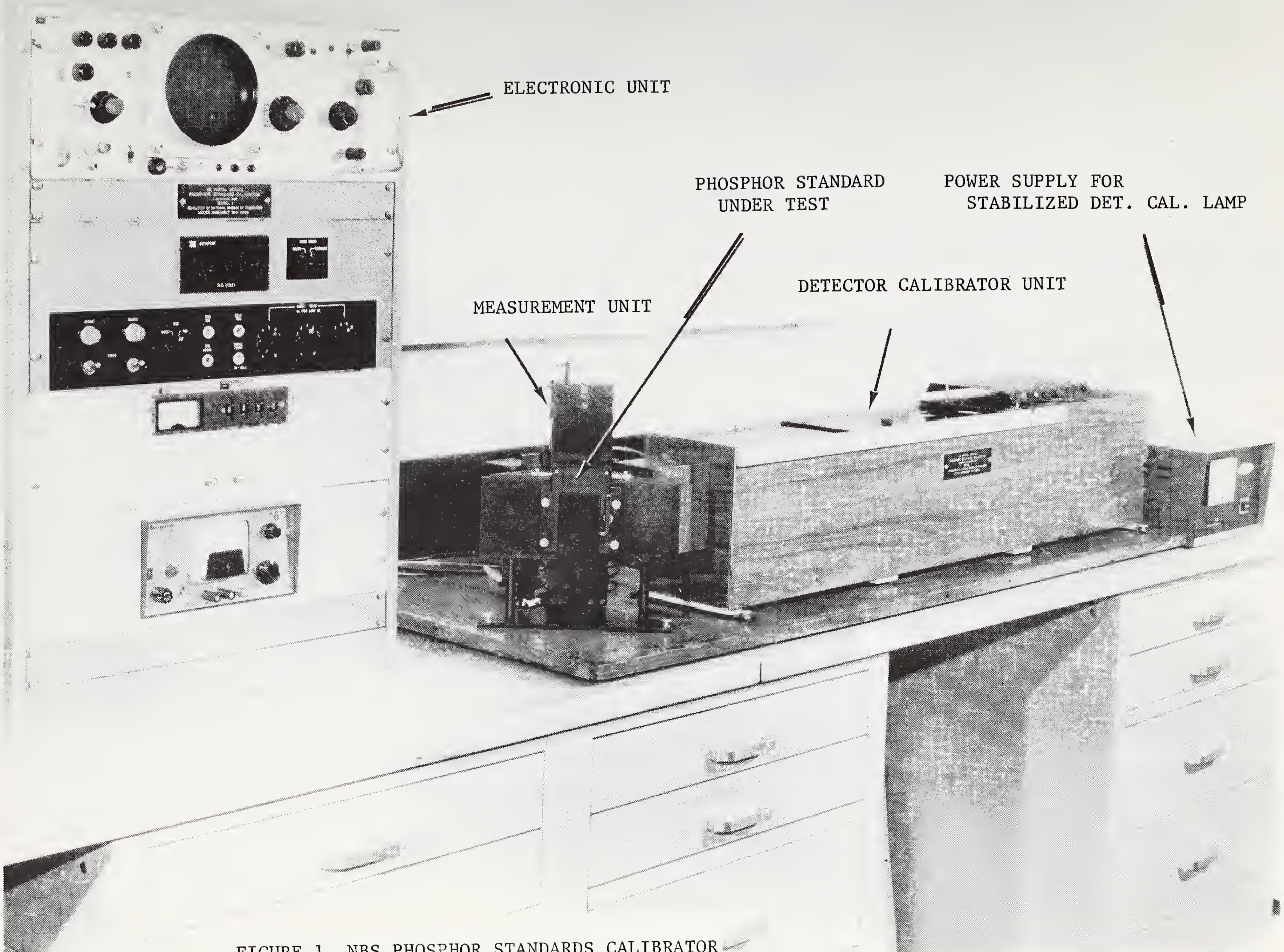


FIGURE 1 NBS PHOSPHOR STANDARDS CALIBRATOR

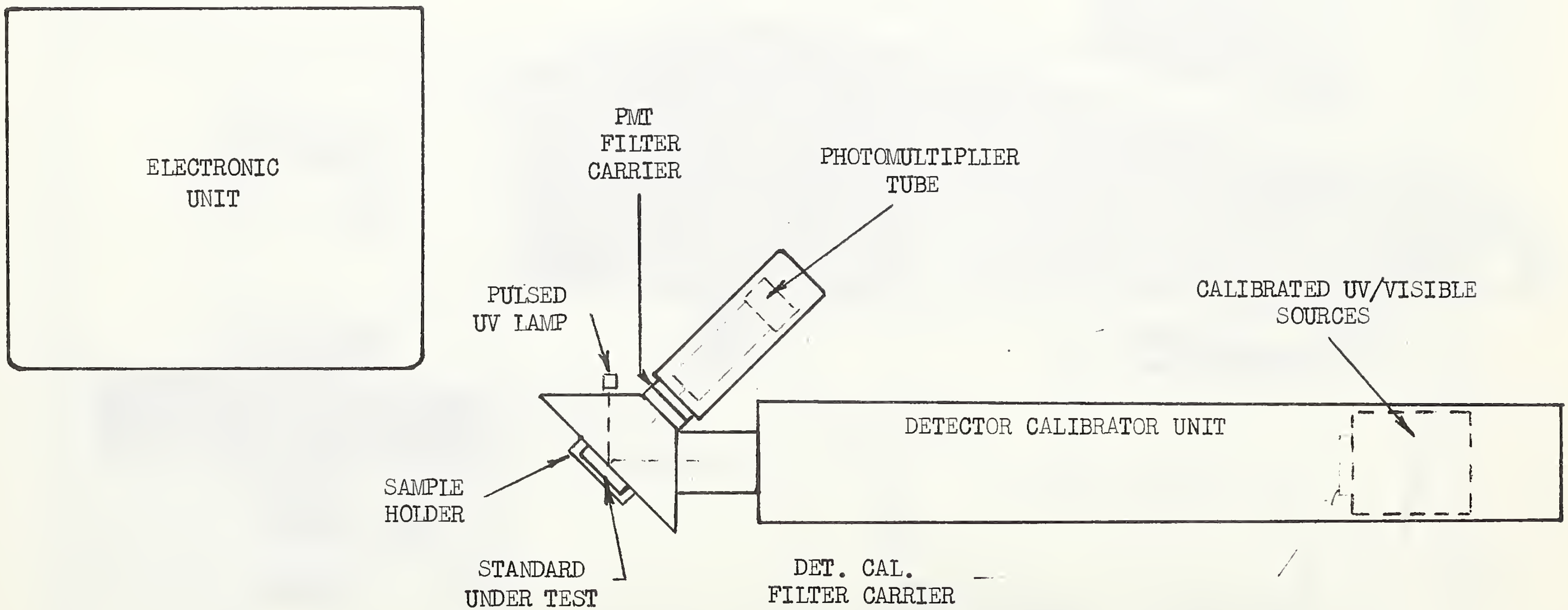


FIGURE 2 OVERALL PLAN, PHOSPHOR STANDARDS INSTRUMENTATION

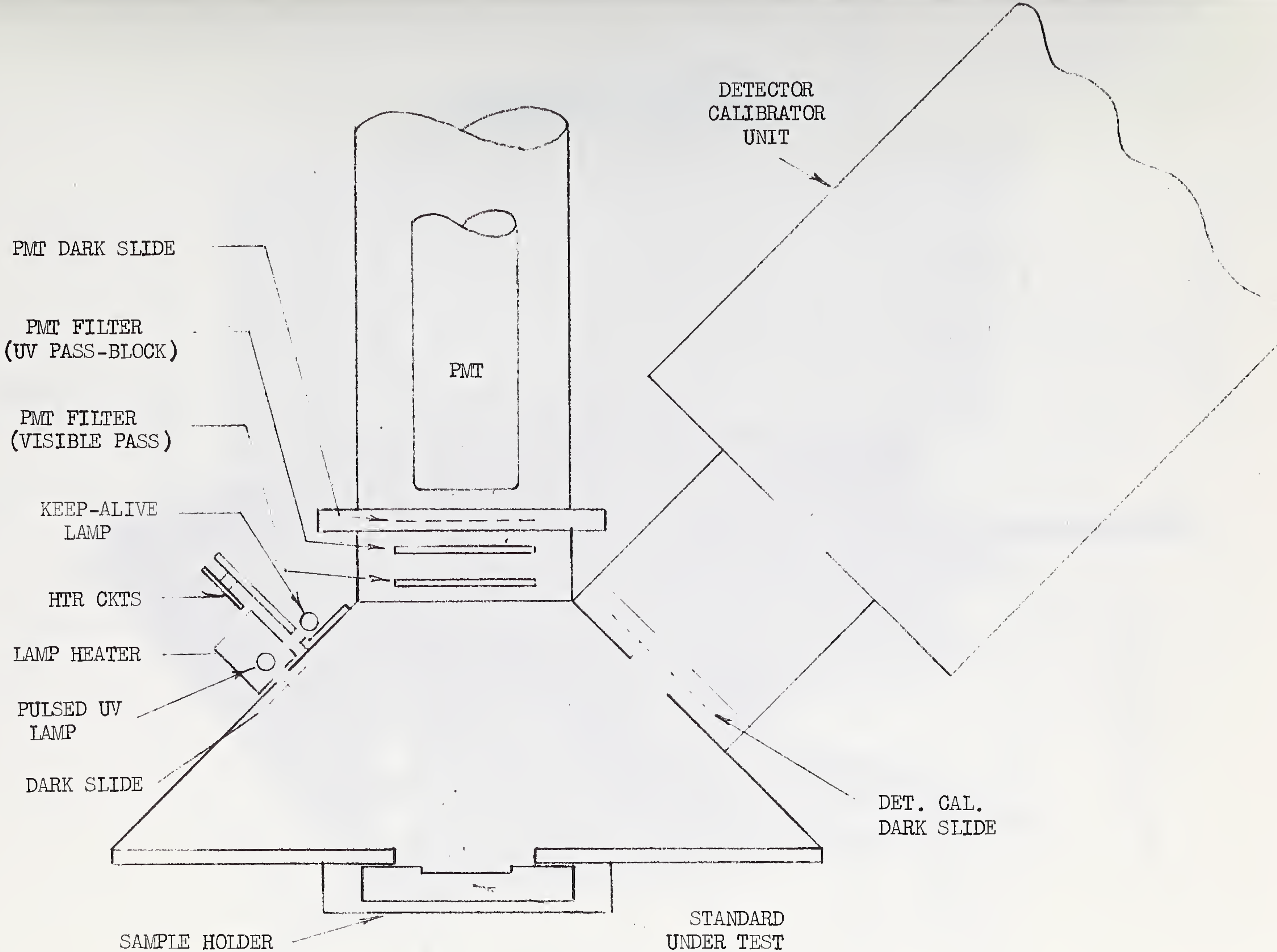


FIGURE 3 MEASUREMENT UNIT, PHOSPHOR STANDARDS INSTRUMENTATION

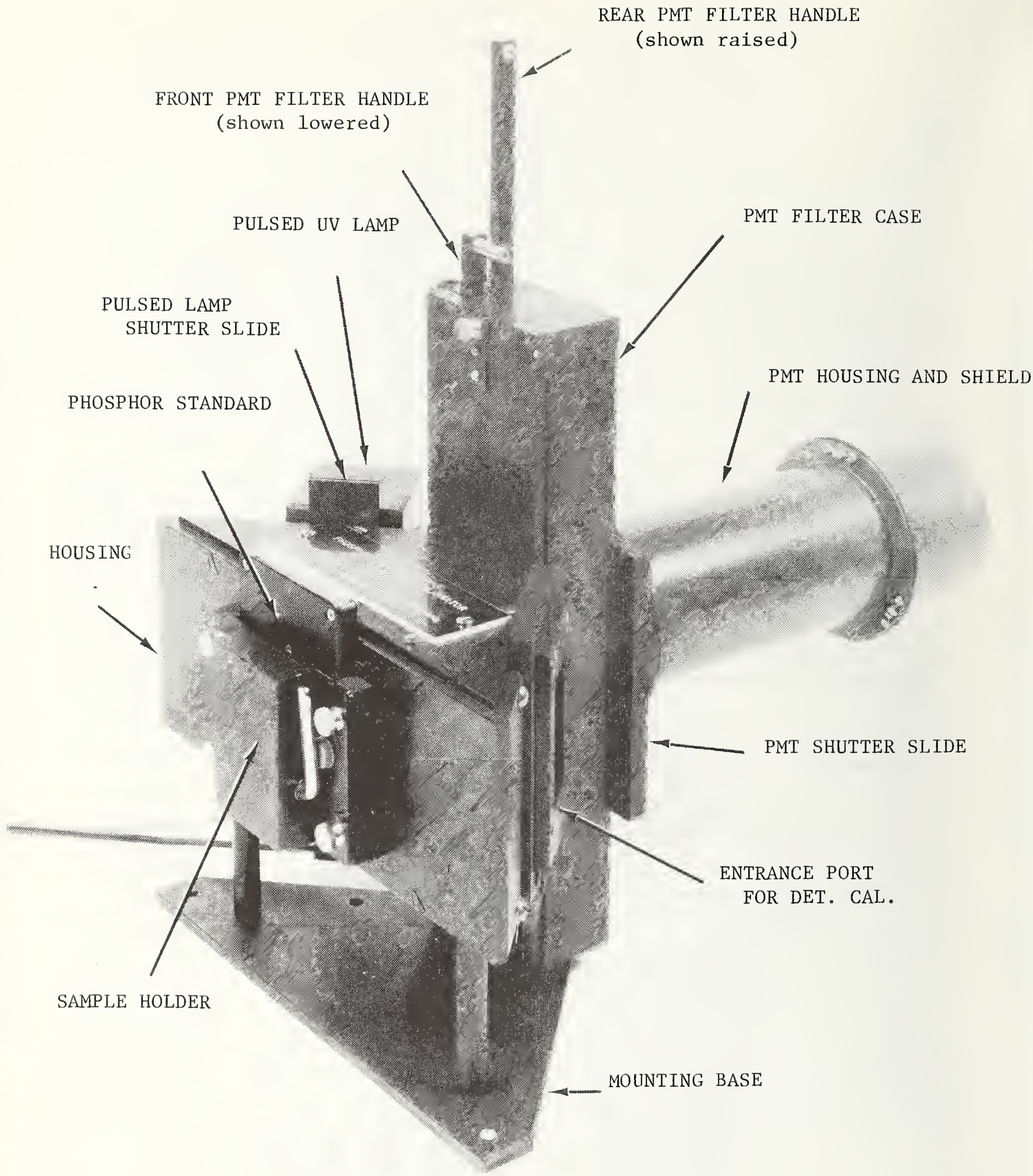


FIGURE 4 MEASUREMENT UNIT

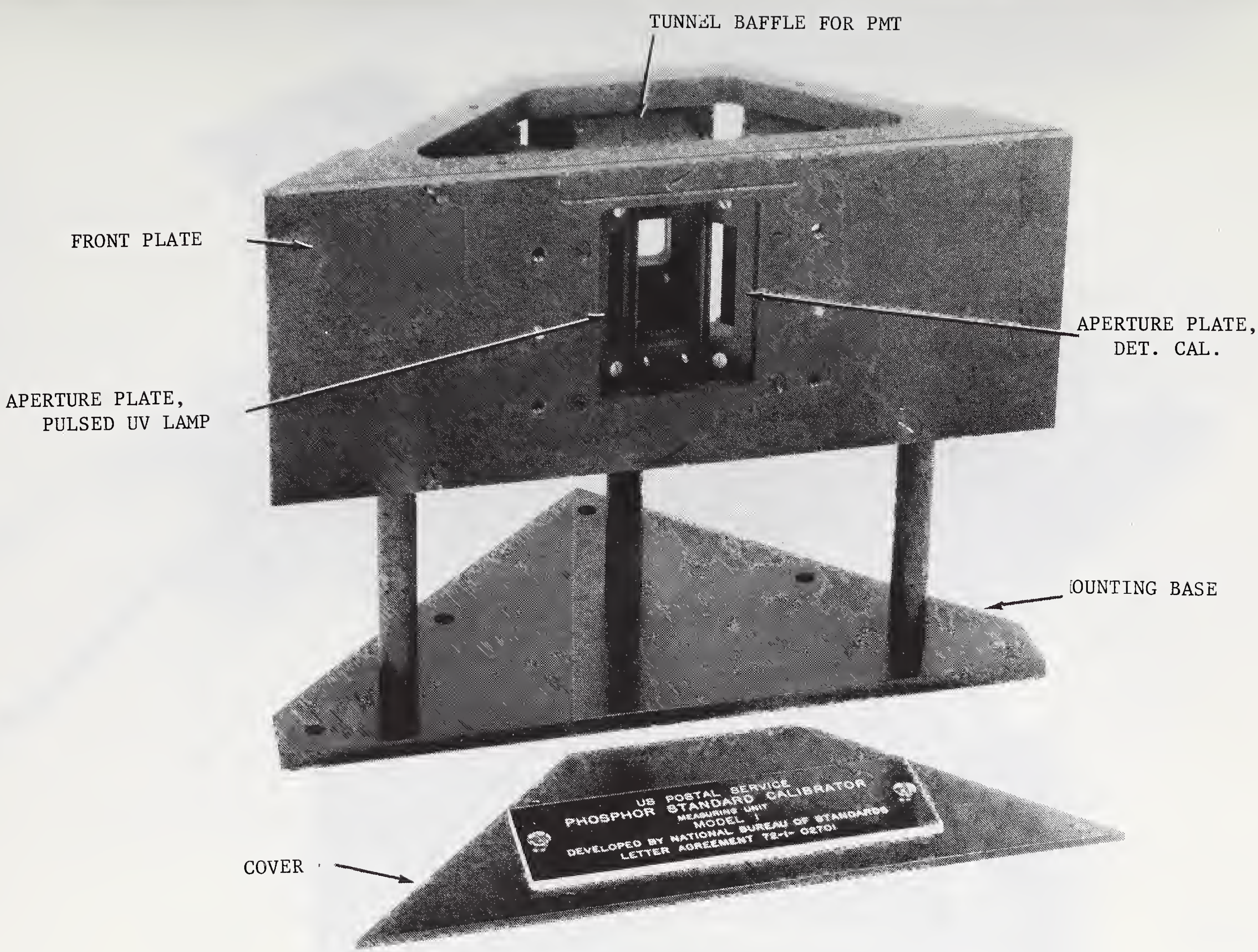


FIGURE 5 FRONT VIEW OF MEASUREMENT UNIT, PARTIALLY DISASSEMBLED

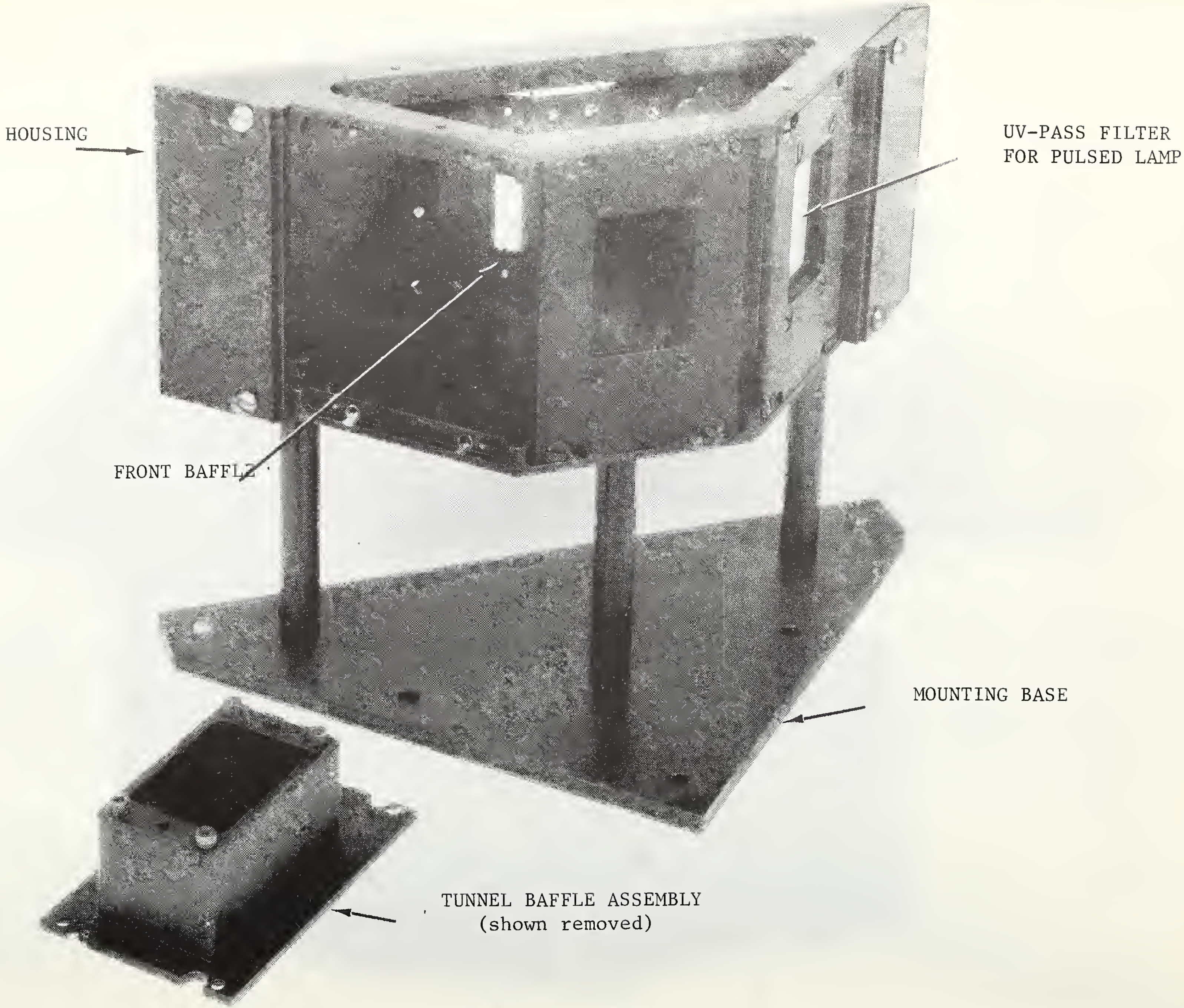


FIGURE 6 REAR VIEW OF MEASUREMENT UNIT, PARTIALLY DISASSEMBLED

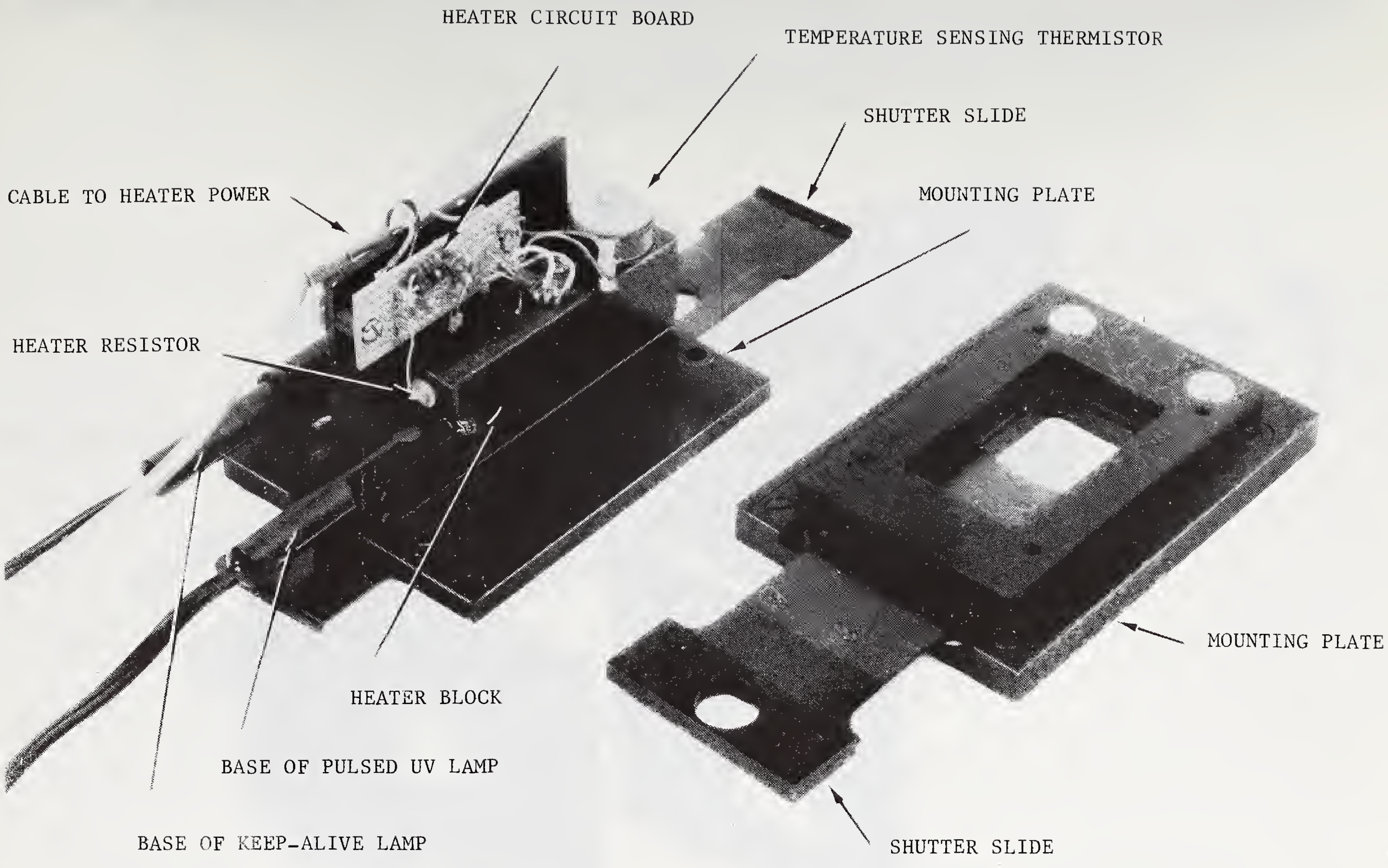


FIGURE 7 PULSED UV LAMP AND ENTRANCE PORT FOR DETECTOR CALIBRATOR

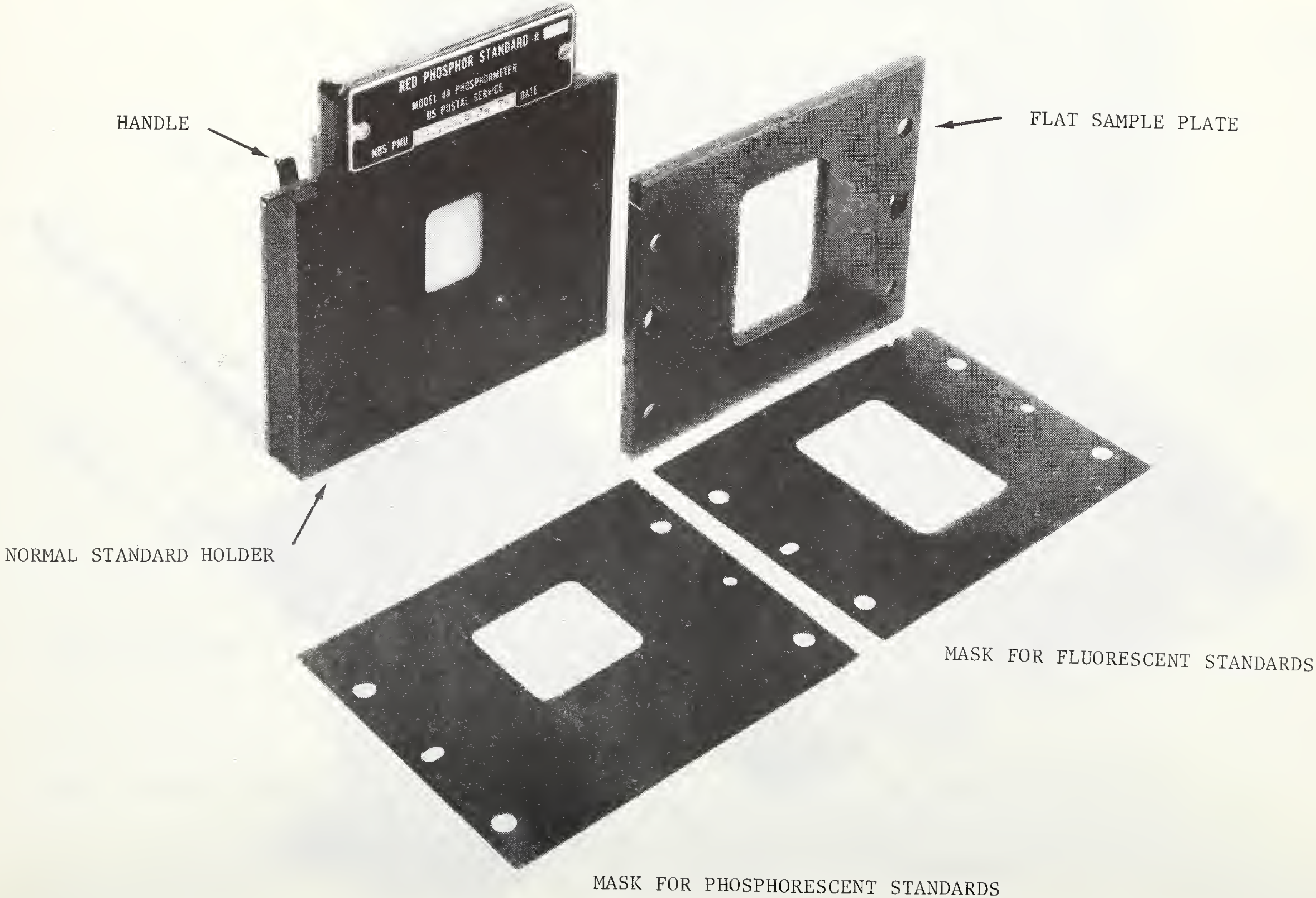


FIGURE 8 SAMPLE HOLDERS

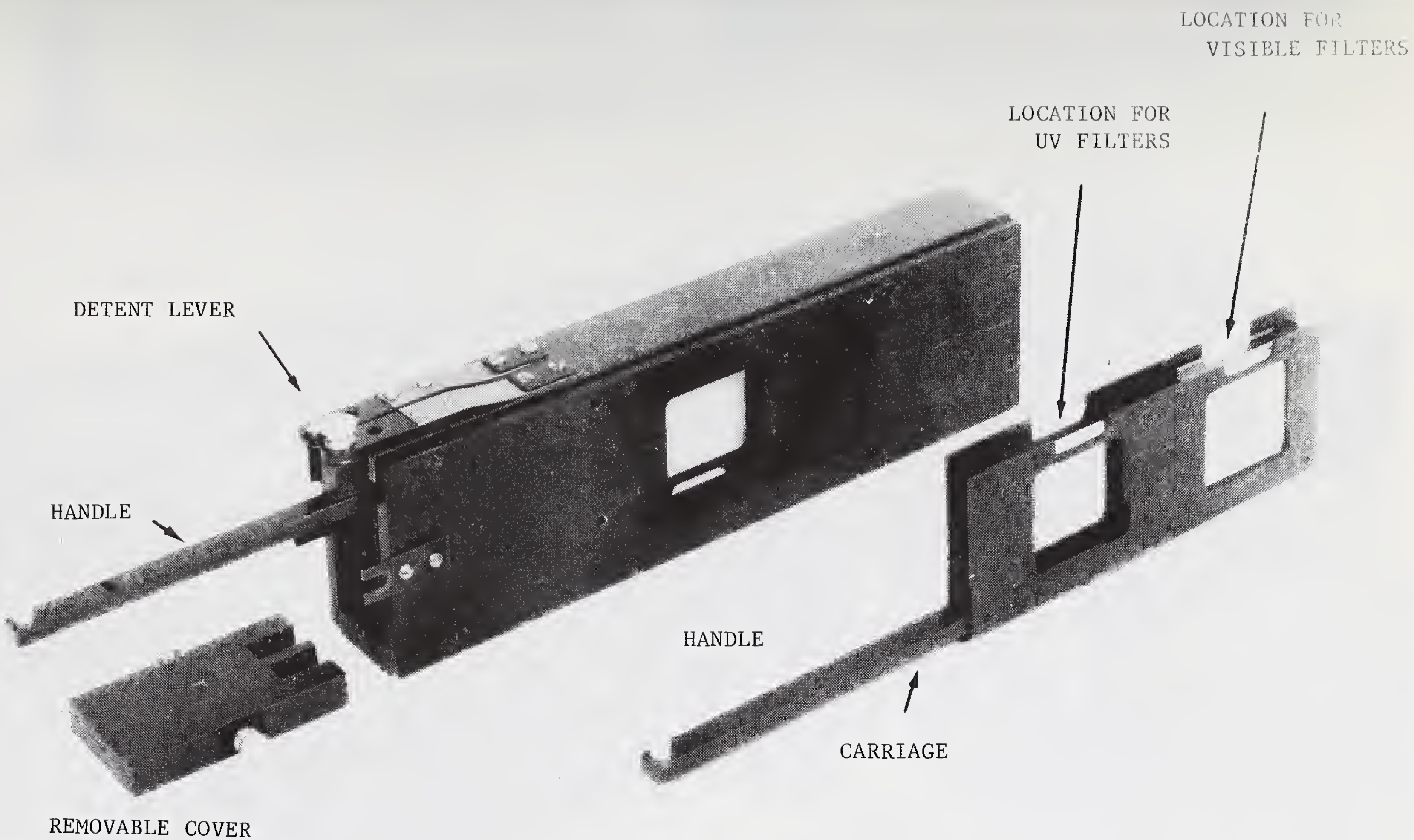


FIGURE 9 FILTER CASE

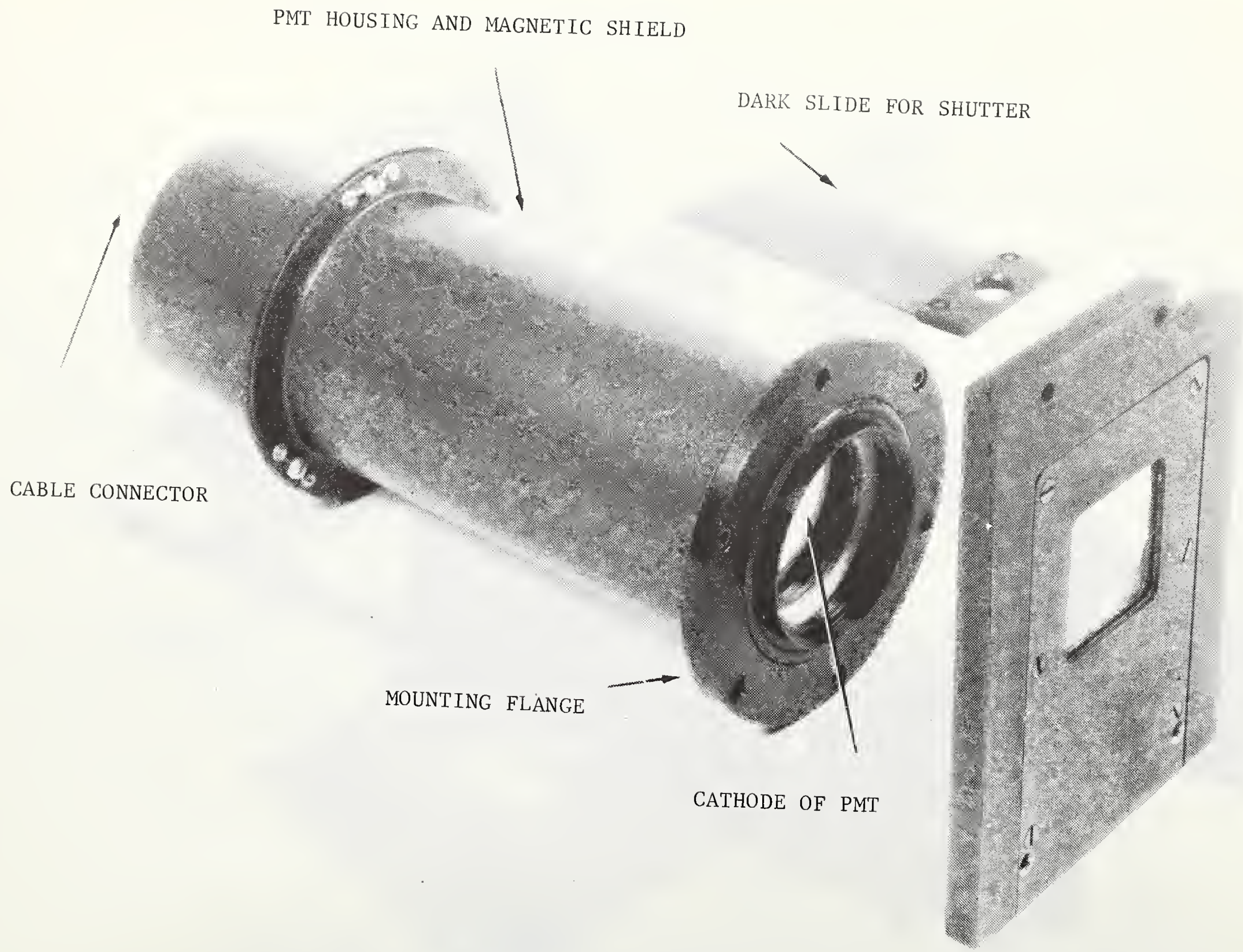


FIGURE 10 PHOTOMULTIPLIER HOUSING AND SHUTTER WITH DARK SLIDE

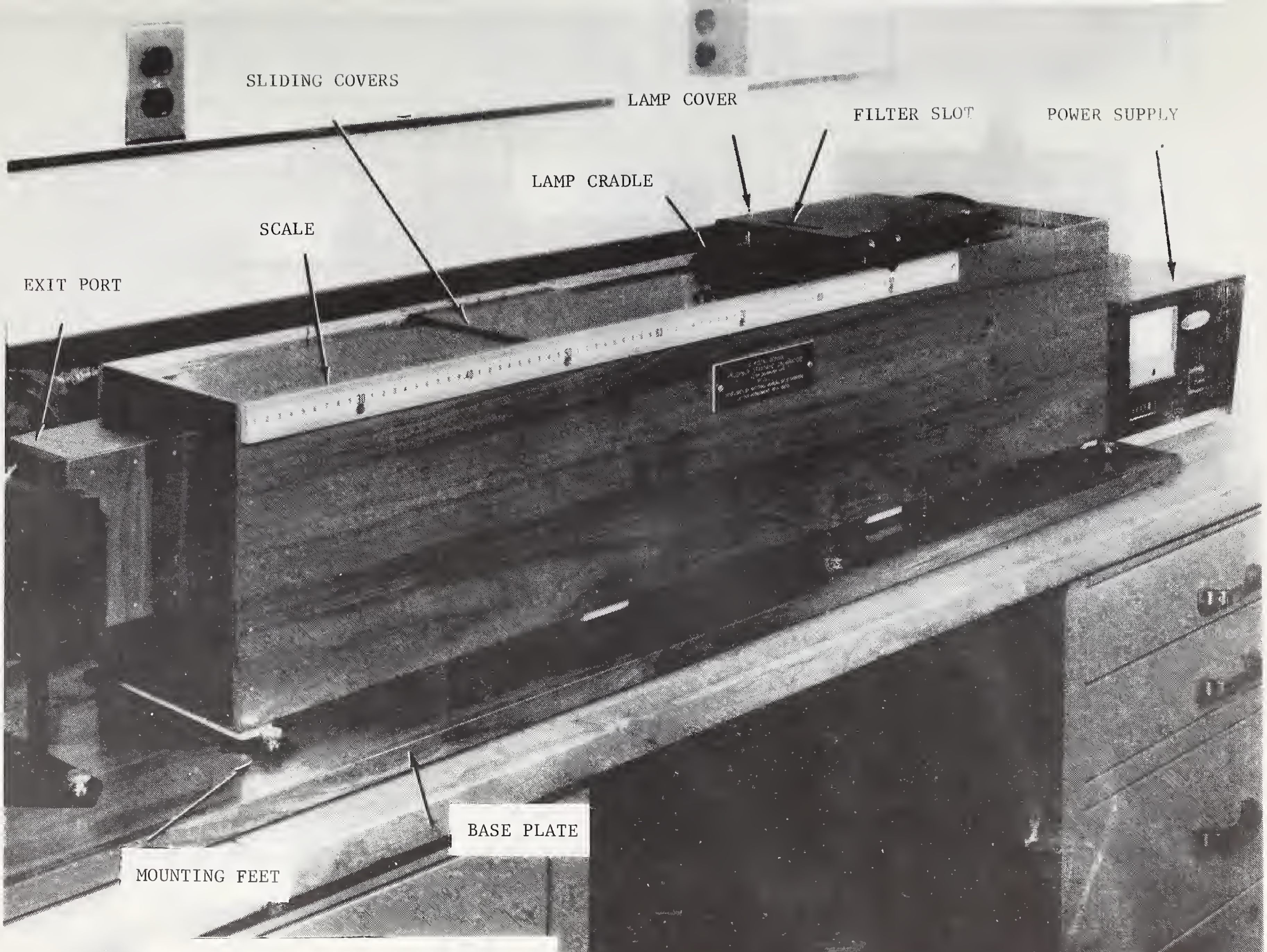


FIGURE 11 DETECTOR CALIBRATOR UNIT

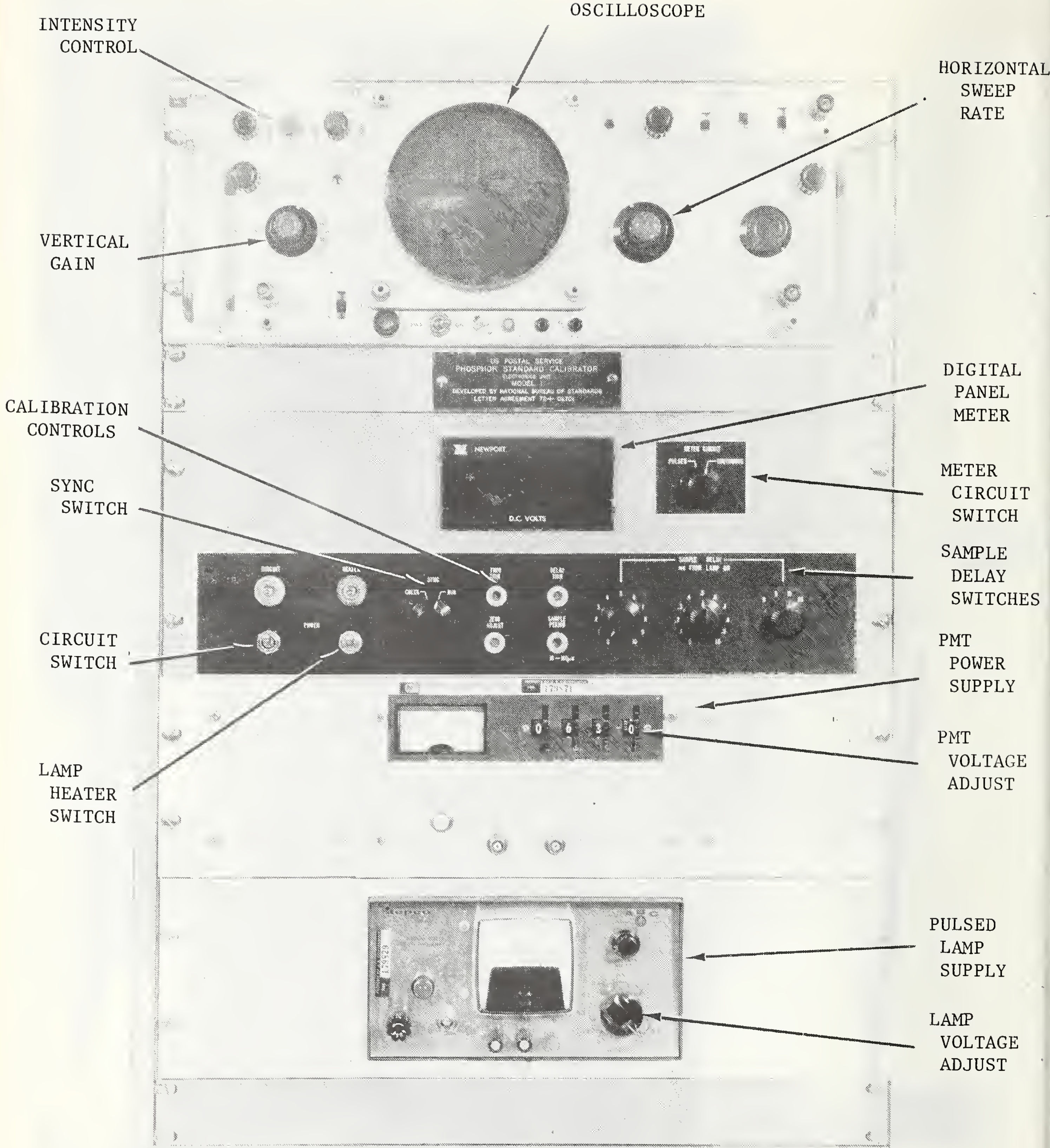


FIGURE 12 CONTROL PANEL OF ELECTRONICS UNIT

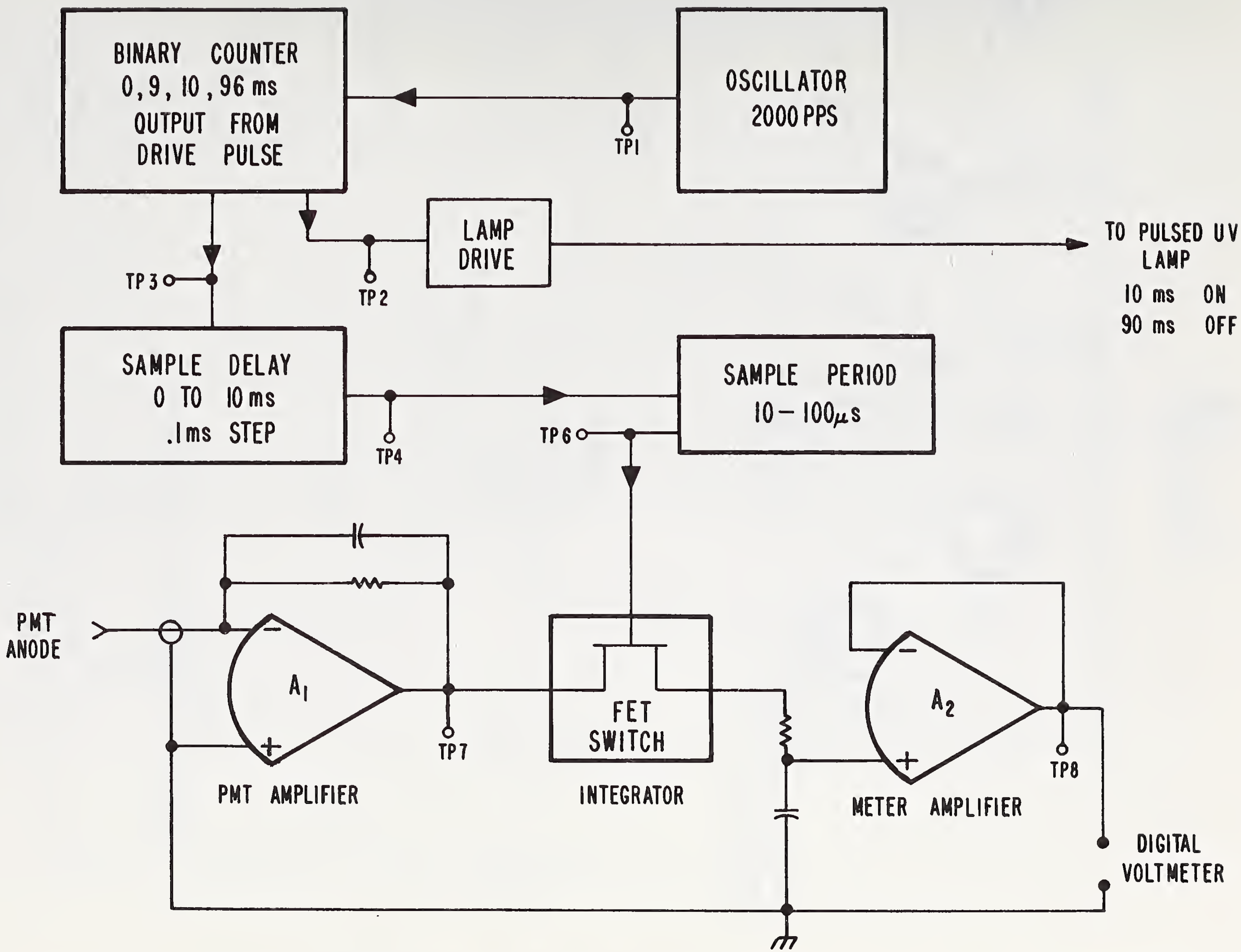


FIGURE 13 BLOCK DIAGRAM OF ELECTRONICS UNIT

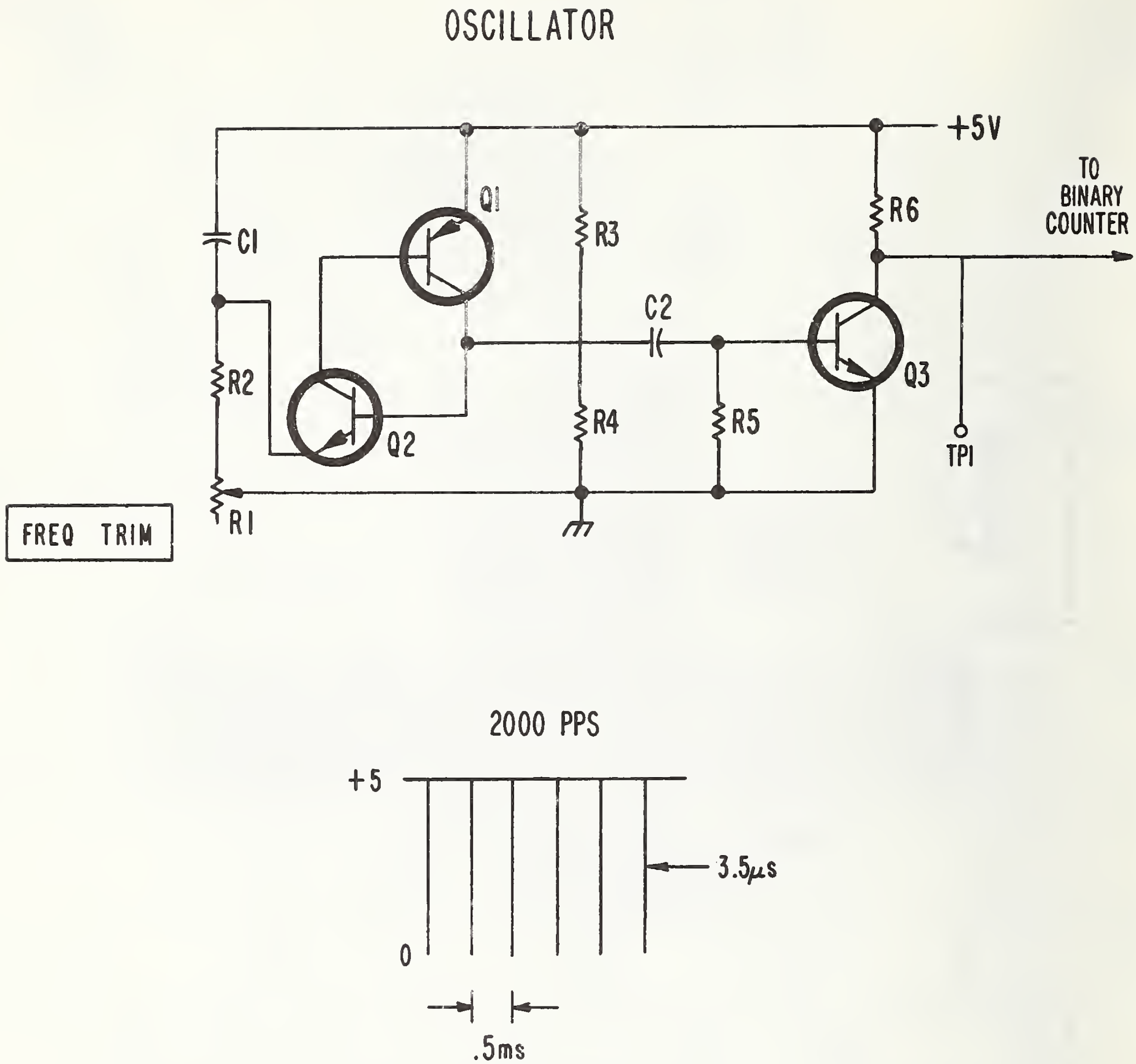


FIGURE 14 DIAGRAM OF OSCILLATOR

BINARY COUNTER

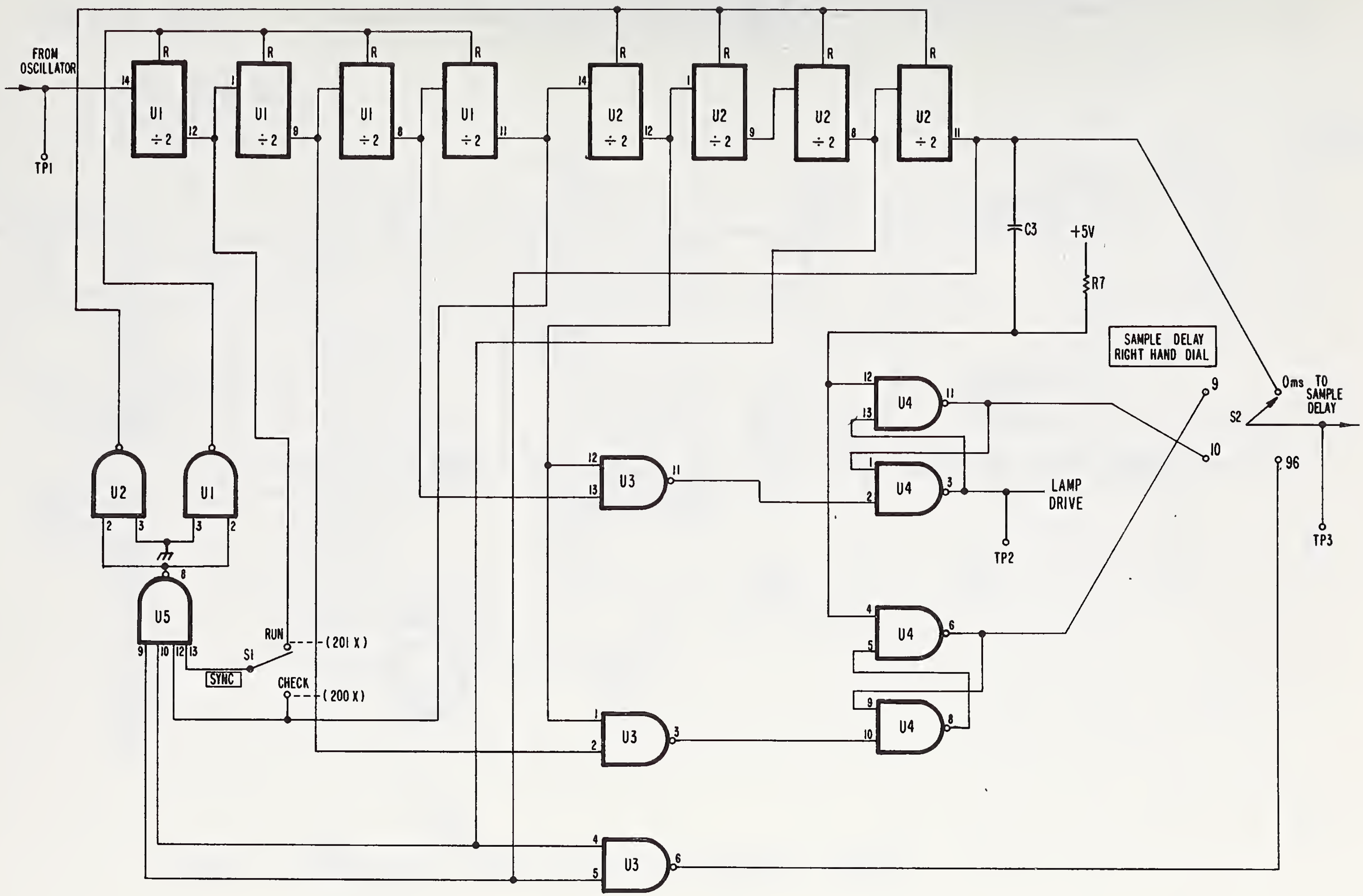


FIGURE 15 DIAGRAM OF BINARY COUNTER

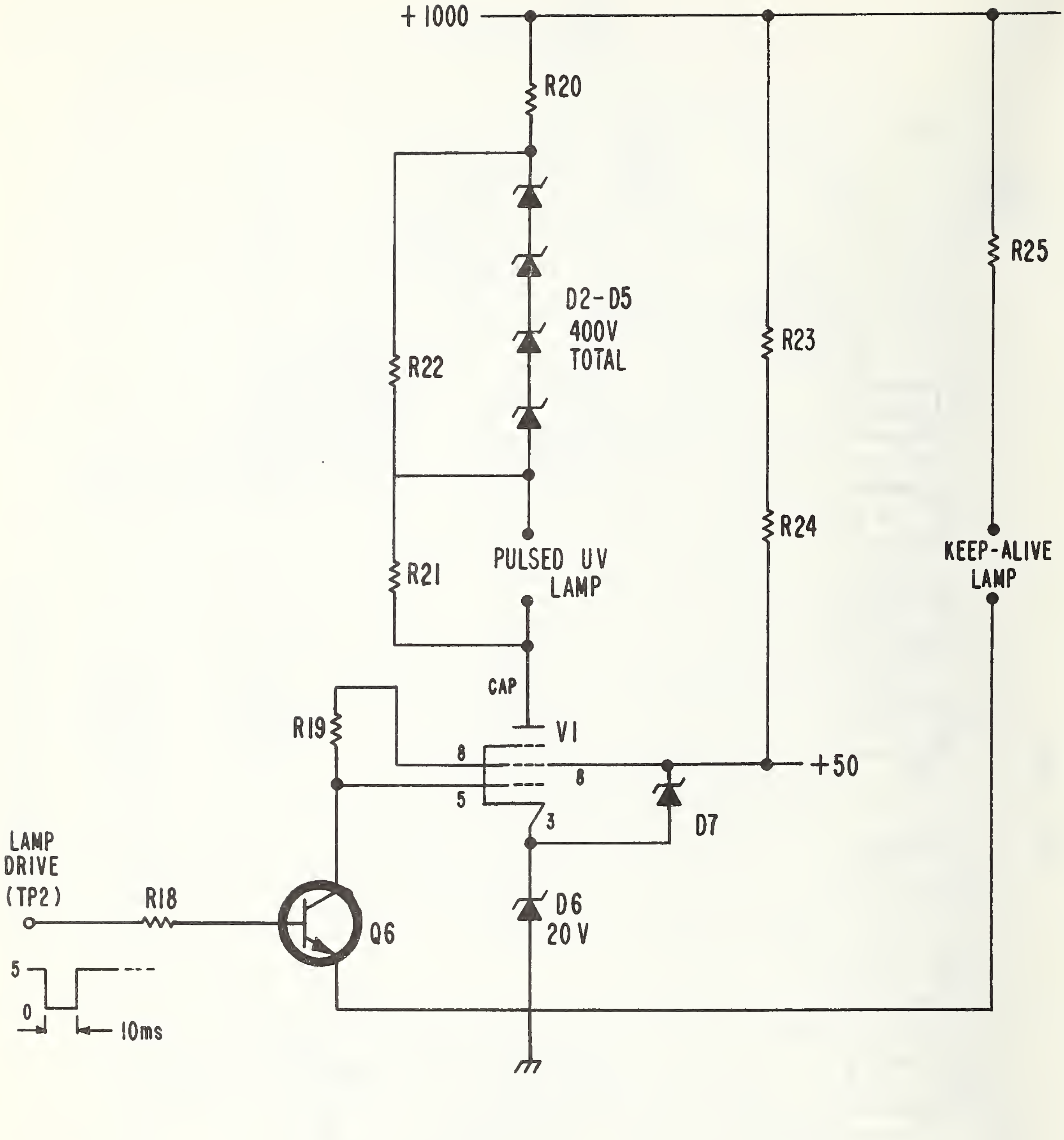


FIGURE 16 DIAGRAM OF LAMP DRIVE

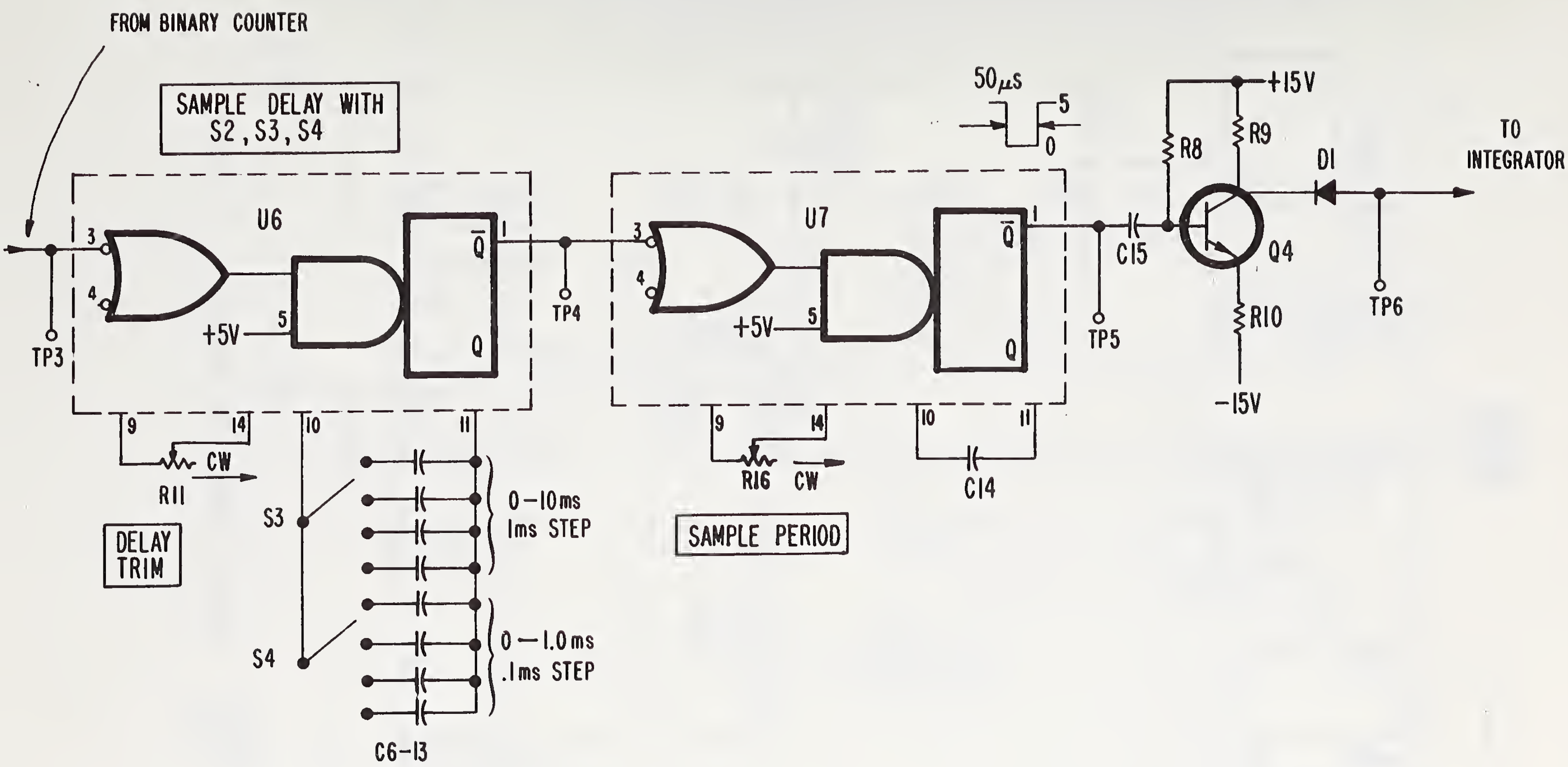


FIGURE 17 DIAGRAM OF SAMPLE DELAY AND SAMPLE PERIOD

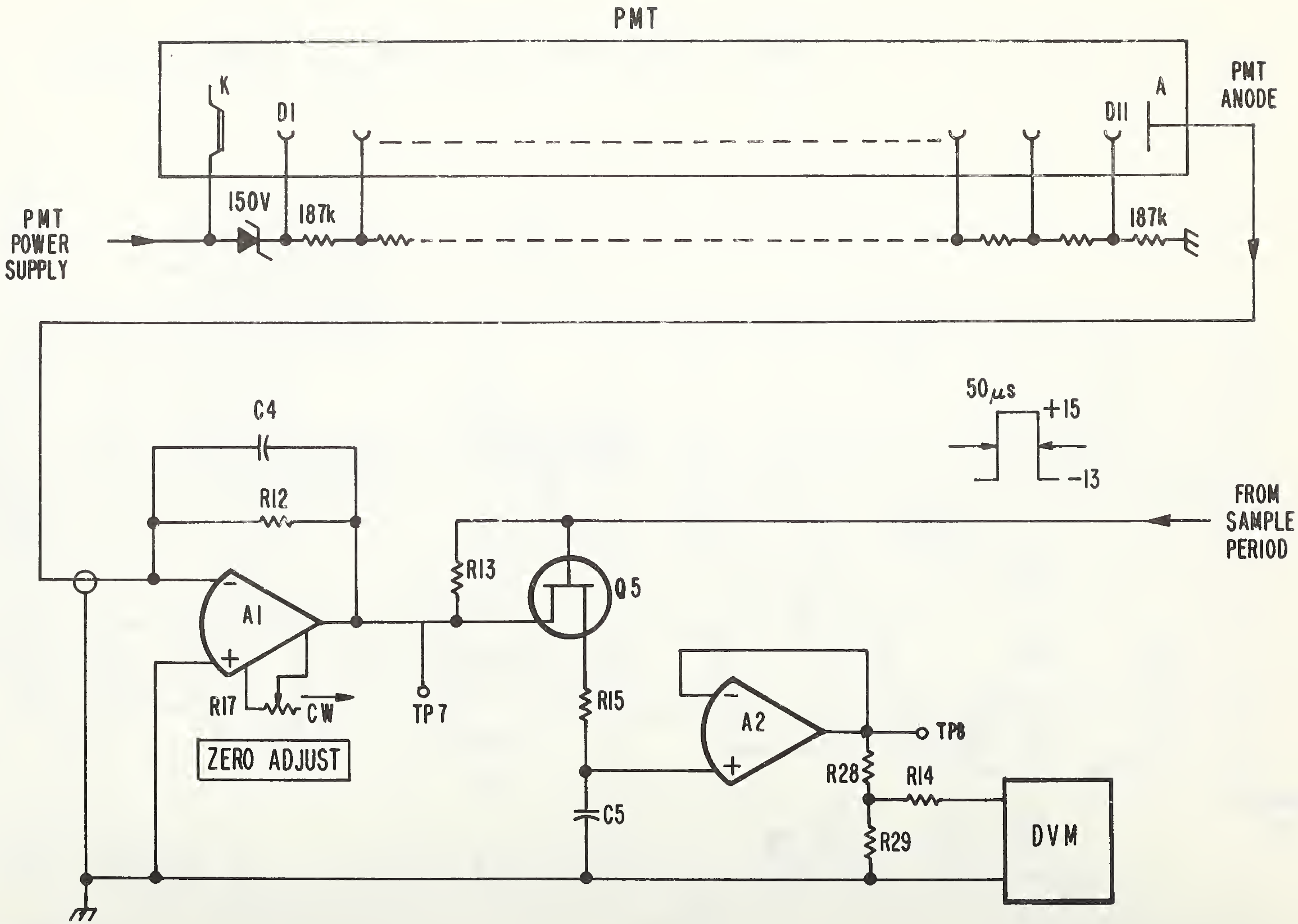
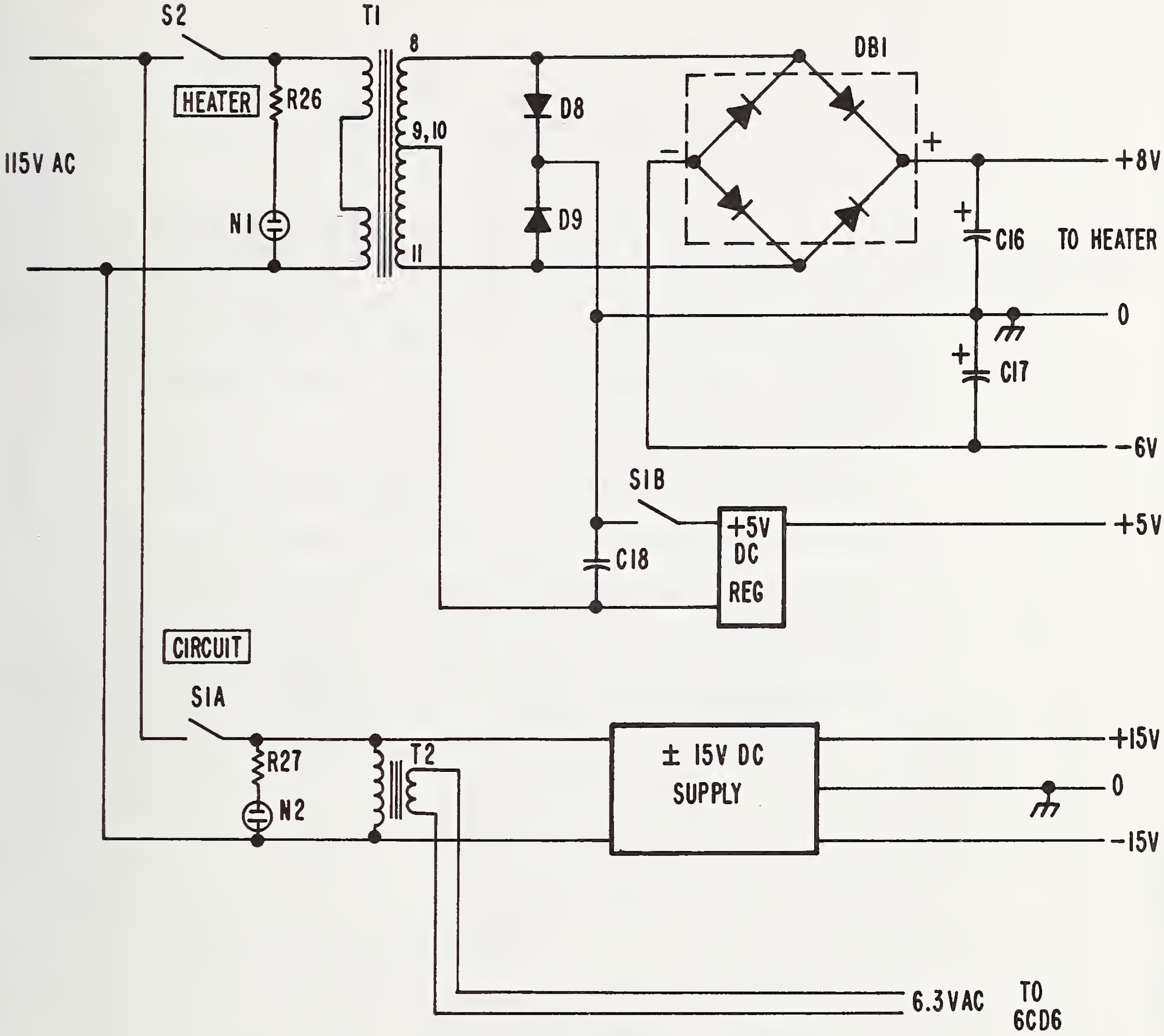


FIGURE 18 DIAGRAM OF PMT CIRCUITS



NOTE — OTHER POWER SUPPLIES CONNECTED DIRECTLY TO LINE OUTLETS

FIGURE 19 DIAGRAM OF POWER WIRING

Test Point List

Test Point No.	Displayed Signal	Source of Waveform Description
1	Oscillator output	Sect. 2.2d(1), Fig. 14
2	Pulsed lamp drive	Sect. 2.2d(2), Fig. 15
3	Sample delay (digital)	Sect. 2.2d(2), Fig. 15
4	Sample delay (analog)	Sect. 2.2d(4), Fig. 17
5	Sample period	Sect. 2.2d(5), Fig. 17
6	Sample period (gate)	Sect. 2.2d(5), Fig. 17
7	PMT output	Sect. 2.2d(7), Fig. 18
8	Integrator output	Sect. 2.2d(8), (9), Fig. 18

FIGURE 20 TEST POINT LIST

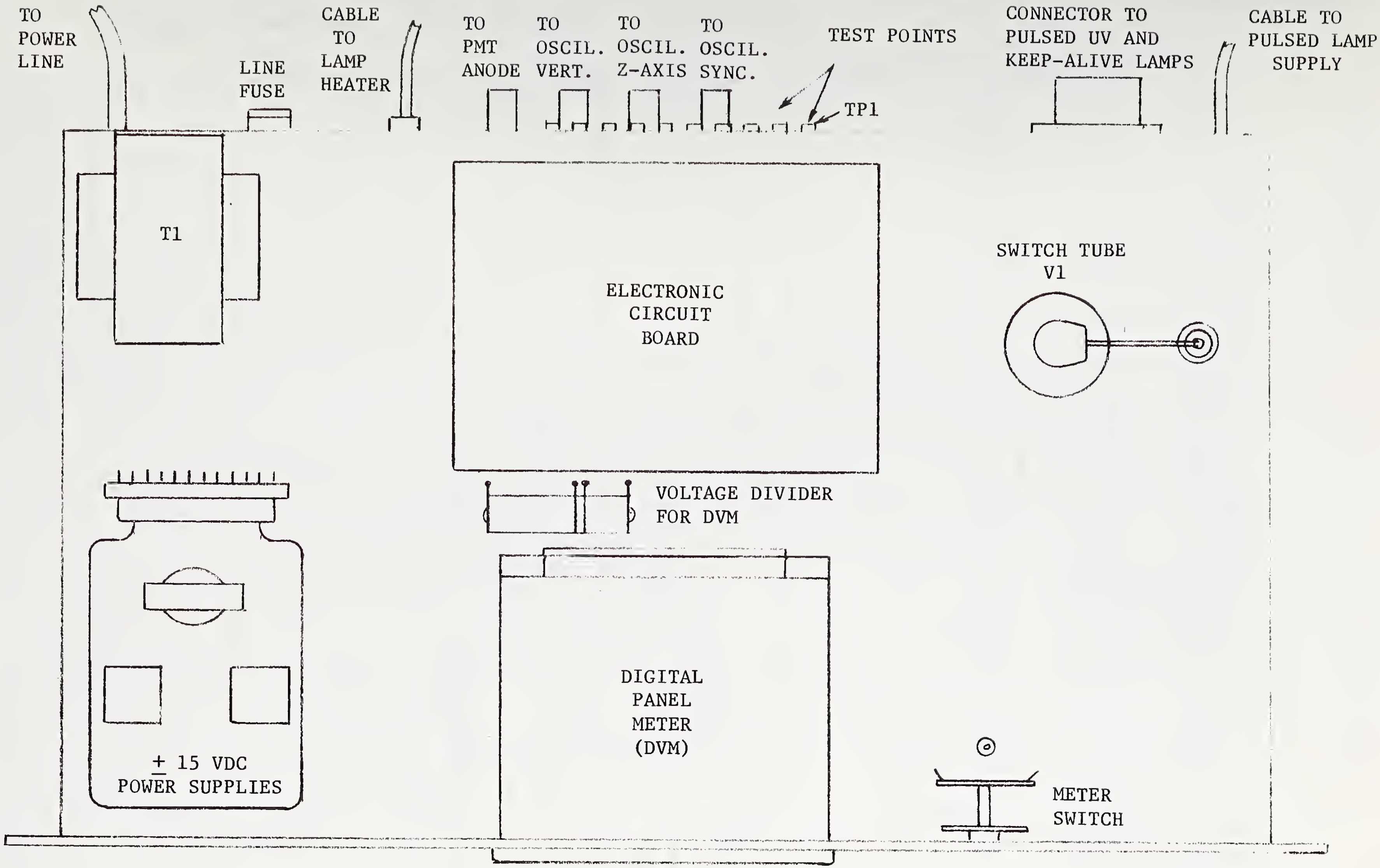


FIGURE 21 COMPONENT LOCATION, ELECTRONIC CHASSIS

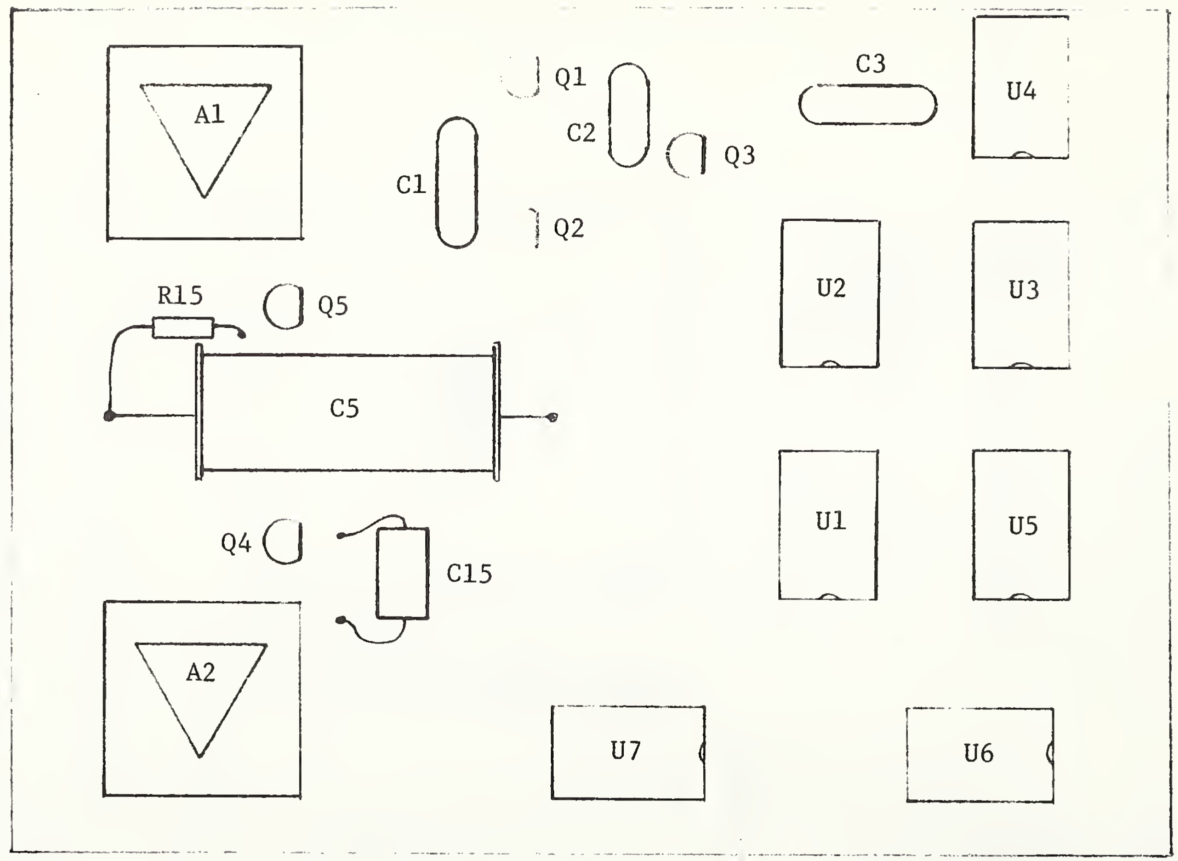


FIGURE 22 COMPONENT LOCATION, ELECTRONIC CIRCUIT BOARD

Phosphorescence $E_{pc} = 730\,V$

Lab. No. ______ **Sheet No.** 1 **Date** 5/31/74

Time	Time delay	Std.	Instr. Rdg.	Weight coeff.- Green	(4)×(5)	Weight Av. $\frac{\Sigma(6)}{\Sigma(5)}$	$-N_2$	P. R. $\frac{(8)}{(7)}$	(9) ×D.R. (.0666)	Efficacy (10) × 0.157
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
10 10	0.5	$BaSO_4$ F27	1.724	.11	.1896	1.661				
	1.5		1.683	.13	.2188					
	2.5		1.678	.15	.2517					
	3.5		1.669	.18	.3004					
	4.5		1.672	.22	.3678					
	5.5		1.672	.26	.4347					
	6.5		1.658	.33	.5471					
	7.5		1.658	.42	.6964					
	8.5		1.647	.56	.9223					
	9.5		1.650	.81	1.3365					
				Σ= 3.17	Σ=5.2653					
	10.5	G258	.340			1.660	.336	.202	.0135	.00212
		G 20	.341				.337	.203	.0136	.00214
		21	.342				.338	.204	.0136	.00214
		23	.322				.328	.198	.0132	.00207
		24	.344				.340	.205	.0137	.00215
		25	.339				.335	.202	.0135	.00212
		26	.352				.348	.210	.0140	.00220
		27	.348				.344	.207	.0138	.00217
		28	.347				.343	.207	.0138	.00217
10 19		G258	.343				.339	.204	.0136	.00214

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FIG. 23 SAMPLE DATA SHEET (Sheet 1 of 3)

Lab. No. ________ Sheet No. 2 Date 5/31/74

Time	Time delay	Std.	Instr. Rdg.	Weight coeff.- Red	(4) x (5)	Weight Av. Σ(6)/Σ(5)	- N2	P. R. (8)/(7)	(9) x D. R. (.0668)	Efficacy (10) x 0.157
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
10 19	10.5	G 258	.343			1.657	.339	.205	.0137	.00215
		G 41	.735				.731	.441	.0295	.00463
10 32		N2	.004							
10 34	0.5	F27	1.691	.54	.9131	1.655				
	1.5		1.660	.56	.9296					
	2.5		1.655	.58	.9599					
	3.5		1.653	.61	1.0083					
	4.5		1.655	.65	1.0758					
	5.5		1.657	.68	1.1268					
	6.5		1.648	.72	1.1866					
	7.5		1.652	.76	1.256					
	8.5		1.648	.82	1.351					
10 36	9.5		1.648	.90	1.483					
			Σ =	6.82	Σ = 11.290					
1037	10.5	R458	.170			1.652	.166	.100	.00668	.00105
		R 20	.153				.149	.090	.00601	.000943
Detector		Calibrator			E_{pc} = 830 V		CONT.			
254 nm		.123	= 0.0668		= D.R.					
546 nm		1.840								

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FIG. 23 SAMPLE DATA SHEET (Sheet 2 of 3)

Lab. No. ______ Sheet No. 3 Date 5/31/74

Std.	Efficacy	NBS-PMU (2)×10288 Green	PMU (3)+1.0	NBS-PMU (2)×14878 Red	PMU (5)+8.0					
(1)	(2)	(3)	(4)	(5)	(6)					
G 258	.00212	21.8	22.8							
G 20	.00214	22.0	23.0							
21	.00214	22.0	23.0							
23	.00207	21.3	22.3							
24	.00215	22.1	23.1							
25	.00212	21.8	22.8							
26	.00220	22.6	23.6							
27	.00217	22.3	23.3							
28	.00217	22.3	23.3							
G258	.00214	22.0	23.0							
G258	.00215	22.1	23.1							
G 41	.00463	47.6	48.6							
R 458	.00105			15.6	23.6					
R 20	.000943			14.0	22.0					

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FIG. 23 SAMPLE DATA SHEET (Sheet 3 of 3)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This project involved two activities, 1) the fabrication and calibration of phosphor standards for use in the Postal Service Model 4A8 Phosphormeter and 2) the construction of an instrument to perform the calibration function. Both of these relate to standarization of the phosphorescent and fluorescent activity of the luminescent coating applied to postage stamps by the Bureau of Engraving and Printing. The purpose of the luminescent coatings is to facilitate detecting the orientation of envelopes in facer-canceler machines during mail processing.

Work on the project entailed the fabrication of approximately 60 phosphor standards, which are hand-sized aluminum blocks into which stamp-sized wafers of luminescent materials are mounted. Fabrication was carried out following the specific procedures supplied by the Postal Service, with however, authority to verify or alter the process as necessary. On the other major project effort, an instrument was designed and constructed following in general the basic design of an earlier breadboard device developed under a prior project. In the system, quantitative evaluations are ultimately referred to calibrations at NBS of the relative irradiance of a lamp in the ultraviolet and visible regions of the spectrum.

This report, one of two covering the project, is in the form of a technical manual for the calibration instrument, and includes theory of operation, mechanical construction and detailed operating procedures.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Fluorescence measurement; Instrumentation, luminescence measuring; Luminescence measurement; Phosphorescence measurement

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