8850
Photomultiplier

51-mm (2-inch) Diameter
12-Stage, End Window Quantacon™ PMT

The BURLE 8850 is a 12-Stage, end-window, 51-mm (2-inch) Quantacon™ photomultiplier employing a semi-transparent bialkali photocathode and an extremely high-gain gallium-phosphide first dynode followed by high-stability copper-beryllium dynodes in the succeeding stages. The 8850 is highly useful for detection in extremely low-light level measurement applications in the blue region of the spectrum. Typical applications include single photon counting, pollution monitoring, radiometry, Raman spectroscopy, scintillation counting, nuclear "time-of-flight" measurements, and astronomy.

The first dynode of these Quantacon™ photomultipliers provides up to an order of magnitude increase in secondary-emission ratio over conventional dynode materials. This high ratio provides a pulse height resolving capability that permits discrimination of up to five or more photoelectron events.

The high gain of the gallium-phosphide dynode in conjunction with the excellent photoelectron collection from all parts of the photocathode is an important feature of the 8850; it provides a photon counting efficiency that is nearly equal to the quantum efficiency of the photocathode. Photon counting efficiency is equal to the ratio of the photon-originated output pulses to the number of photons incident on the faceplate.

General Data

Spectral Response .... See **Figure 1**
 Wavelength of maximum response .... 420 nanometers
Cathode Description:
 Material .... Potassium-Cesium-Antimony (Bialkali)
 Minimum projected area .... 16.4 sq. cm (2.54 sq. in)
 Minimum useful diameter .... 45.7 mm (1.80 in)
Faceplate Description:
 Material .... Pyrex, Corning[1] No. 7740, or equiv.
 Shape .... Plano-Concave
 Index of refraction, 589.3 nanometers 1.47

- **Low Dark Noise**
- **High Gain**
- **Low-Light Level Applications**
- **High Photon Counting Efficiency**
- **High-Stability Dynodes**

Dynode Description:
 Dynode no.1 secondary emitting surface .... Gallium-Phosphide
 Dynode no.2 thru 12, secondary emitting surface .... Beryllium-Oxide
 Structure .... In-Line Electrostatic Focus-Type
Direct Interelectrode Capacitances (Approx):
 Anode to dynode no.12 .... 5 pF
 Anode to all other electrodes .... 6 pF
Socket[2] .... BURLE Types AJ2145A (supplied), AJ2144A (optional)
Magnetic Shield .... BURLE Type AJ2252
Operating Position .... Any
Weight (Approx) .... 170 gms (6 oz)

Absolute-Maximum Ratings - Limiting Values:[3]

DC Supply Voltage:
 Between Anode and Cathode:
  With voltage distribution of Column A, Table 1:[4]
   Maximum .... 3000 V
   Minimum .... 800 V
  With voltage distribution of Column B, Table 1:[4]
   Maximum .... 3000 V
   Minimum .... 1300 V
  With voltage distribution of Column C, Table 1:[4]
   Maximum .... 3500 V
   Minimum .... 2400 V
 Between anode and dynode no.12 .... 800 max. V
 Between dynode no. 12 and dynode no.11 .... 800 max. V
 Between consecutive dynodes .... 400 max. V
 Between dynode no.1 and cathode:[4]
  Maximum .... 1000 V
  Minimum .... 600 V
 Between focusing electrode and cathode .... 1000 max. V
Average Anode Current[5] .... 0.2 max. mA
Temperature:[6]
 Operating and Storage .... -50 to +85 degrees C

BURLE Electron Tubes

Performance Data

Under conditions, except as noted, with supply voltage (E) across a voltage divider providing electrode voltages shown in distribution A, Table 1, and at a temperature of 22 degrees C.

With E = 2000 volts (except as noted)

	Min.	Typ.	Max.	Units
Anode Responsivity:				
Radiant @ 420 nm[7]	--	1.3×10^{6}	--	A/W
Luminous[8]	110	1140	5700	A/lm
Blue Response[9]	15	160	800	A/Blm
Cathode Responsivity:				
Radiant @ 420 nm[10]	--	82	--	mA/W
Luminous[11]	--	71	--	uA/lm
Blue Response[12]	8.0	10.0	--	uA/Blm
Current Amplification	--	1.6×10^{7}	--	
Anode Dark Current @ 200 A/lm[13]	--	0.6	4.5	nA
Equivalent-Anode Dark Current Input @ 200 A/lm[14]	--	3.0×10^{-12}	2.3×10^{-11}	lm
	--	2.6×10^{-15}	2.0×10^{-14}	W
Single Photoelectron Pulse Height Resolution at Full-width-Half Maximum Points[15]	--	40.	--	%
Peak-to-Valley Ratio Between Single and Double Photo-electron Pulse Height[15]	1.4	1.9	--	
Dark Pulse Summation[16] (1/8 to 16 photoelectrons)	--	167.	667.	cps
Peak-to-Valley Ratio of Pulse Height Spectrum With ^{55}Fe source[17]	-	50.	--	
Pulse Height Resolution[18] using ^{137}Cs source and NaI(Tl) Scintillator	-	7.3	--	%
Anode-Pulse Rise Time[19] @ 3000 V	--	2.1×10^{-9}	--	sec
Electron Transit Time[20] @ 3000 V	---	3.1×10^{-8}	--	sec
With E = 3000 volt				
Pulse Current:[21]				
Linear[22]	--	0.25	--	A
Saturated	--	0.75	--	A

Notes

1 Made by Corning Glass Works, Corning, NY 14830.

2 The AJ2145A is ordinarily supplied with the tube and is designed specifically for chassis mounting. The AJ2144A is designed for use in any desired mounting arrangement. It is supplied with an unattached clamp ring which fits to either the top or bottom of its socket body to permit chassis mounting. The ring is not normally required for other mounting arrangements and can be discarded to make such arrangements more compact.

3 In accordance with the Absolute Maximum rating system as defined by the Electronic Industries Association Standard RS-239A, formulated by the JEDEC Electron Tube Council.

4 To take full advantage of the performance capabilities of these tubes, tube operation at voltages above the minimum specified values should be employed.

5 Averaged over any interval of 30 seconds maximum.

6 Operation at room temperature or below is recommended. The use of Teflon sockets with the tube at temperatures below the minimum temperature rating of -50 degrees C can destroy the 8850.

7 This value is calculated from the typical anode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.

8 These values are calculated as shown below:

$$\text{Luminous Sensitivity (A/lm)} = \frac{\text{Anode Blue Response (A/Blm)}}{0.14}$$

The value of 0.14 is an average value. It is the ratio of the anode current measured under the conditions specified in footnote (9) to the anode current measured under the same conditions but with the blue filter removed.

9 Under the following conditions: Light incident on the photocathode is transmitted through a blue filter (Corning C.S. No. 5-58, polished to 1/2 stock thickness) from a tungsten-filament lamp operated at a color temperature of 2856 K. The value of light flux incident on the filter is 10^{-7} lumens.

10 This value is calculated from the typical cathode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.

11 This value is calculated as shown below:

$$\text{Cathode Luminous Sensitivity (uA/lm)} = \frac{\text{Cathode Blue Response (uA/Blm)}}{0.14}$$

The value 0.14 is an average value. It is the ratio of the cathode current measured under the conditions specified in footnote (12) to the same conditions but with the blue filter removed.

12 Under the following conditions: Light incident on the photocathode is transmitted through a blue filter (Corning C.S. No. 5-58, polished to 1/2 stock thickness) from a tungsten-filament lamp operated at a color temperature of 2856 K. The value of light flux incident on the filter is 10^{-4} lumens and 300 volts are applied between cathode and all other electrodes connected as anode.

13 Under the following conditions: At a tube temperature of 22 degrees C the light incident on the photocathode is transmitted through a blue filter (Corning C.S.No. 5-58, polished to 1/2 stock thickness). The light flux incident on the filter is 10^{-7} lumens. The supply voltage (E) is adjusted to obtain an anode current o 2.6 microamperes. Luminous sensitivity of the tube under these conditions is approximately equivalent to 200 amperes per lumen. Dark current is measured with the incident light removed.

14 Equivalent Anode Dark Current Input (EADCI) is defined as the input flux in lumens or watts at a specific wavelength which results in an increase in the anode current of the photomultiplier tube just equal to the anode dark current. EADCI in watts (@ 420 nm) is calculated from the EADCI value in lumens using a conversion factor of 1140 lumens per watt.

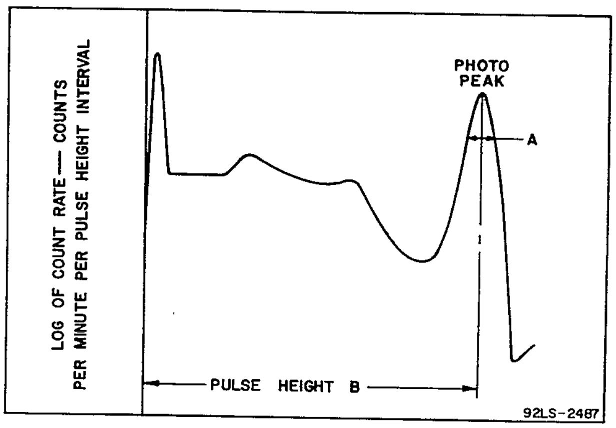
15 Measured under the following conditions: Dark noise is eliminated by use of a coincidence circuit. As a result, most of the low energy pulses below one photoelectron are not counted. The light source is a gallium-phosphide light-emitting diode having peak output at a wavelength of approximately 560 nanometers. The diode is pulsed at a rate of 7000 to 8000 pulses per second; pulse duration is approximately 0.4 microseconds, anode circuit integrating time is approximately 10 microseconds. The light intensity from the diode is adjusted to obtain greater or fewer registered counts in a given multielectron peak to obtain an approximately equal number of counts in the first and second photoelectron peaks. A multi-channel pulse height analyzer having 256 channels is employed. Gain of the tube is approx. 3×10^{7}.

16 Measured with the tube in total darkness. The pulse height for the single photoelectron equivalent is determined by using a light

source operated at a low color temperature to assure the high probability of single photoelectron emission from the photocathode of the tube. The intensity of the light source is adjusted for approximately 10^4 photons per second. This light is removed before dark pulse summation is measured. The supply voltage is adjusted so that the peak of the single electron distribution lies in channel No. 8. This corresponds to a tube gain of approximately 3×10^7.

17 Measured using a Harshaw type HG 0.005" beryllium window NaI(T1) scintillator, 0.04" thick and 0.875" in diameter and an isotope of iron having an atomic mass of 55 (^{55}Fe) and an effective activity at the scintillator of one microcurie.

18 Anode load is a 100 kilohm resistor with a total capacitance of 100 +/- 3 % pF in parallel. The 662 keV photon from a one microcurie ^{137}Cs source and a cylindrical 2" x 2" NaI(Tl) crystal (BURLE No. 2005, or equivalent) are used. The ^{137}Cs source is in contact with the metal end of the scintillator. The faceplate end of the crystal is coupled to the tube by an appropriate coupling fluid such as mineral oil, or equivalent. Pulse height resolution in per cent is



defined as 100 times the ratio of the width of the photopeak at half the maximum count rate in the photopeak height (A) to the pulse height at maximum photopeak count rate (B).

19 Measured between 10 per cent and 90 per cent of maximum anode-pulse height. This anode-pulse rise time is primarily a function of transit time variation and is measured under conditions with the incident light fully illuminating the photocathode.

20 The electron transit time is the interval between the arrival of a delta function light pulse at the entrance window of the tube and the time at which the output pulse at the anode terminal reaches peak amplitude. The transit time is measured under conditions with the incident light fully illuminating the photocathode.

21 Using a pulsed light source having a pulse duration of 0.5 microsecond and repetition rate of 30 pulses per second. The interstage voltage of the tube should not deviate more than 2 per cent from the recommended voltage distribution shown by Voltage Distribution A of Table 1. Capacitors are connected across the individual resistors making up the voltage-divider arrangement to insure this operating condition.

22 Maximum deviation from linearity is 5 per cent.

Operating Considerations

Anode Current

The operating stability of the 8850 is dependent on the magnitude of the average anode current. The use of an average anode current well below the maximum rated value of 200 microamperes is recommended when stability of operation is important. When maximum stability is required, the average anode current should not exceed 1 microampere.

Cathode Current

An average cathode current of 10^{-8} ampere at a tube temperature of 22 degrees C or 10^{-10} amperes at -50 degrees C should not be exceeded. Because of the resistivity of the photocathode, the voltage drop caused by higher average cathode currents may produce radial electric fields which can result in poor photoelectron collection on the first dynode. Photocathode resistivity increases with decreasing temperature.

Shielding

Electrostatic shielding of the tube is ordinarily required. When a shield is used, it must be connected to the cathode terminal. The application of high voltage, with respect to the cathode, to insulating or other materials supporting or shielding the tube at the photocathode end should not be permitted unless such materials are chosen to limit leakage current to the tube envelope to 10^{-12} ampere or less. In addition to increasing dark current and noise output because of voltage gradients developed across the bulb wall, such high voltage may produce minute leakage current to the cathode, through the tube envelope and insulating materials, which can permanently damage the tube.

Ambient Atmospheres

Operation or storage of this tube in environments where helium is present should be avoided. Helium may permeate the tube envelope and may lead to eventual tube destruction.

Anode Dark Current

The base of the tube and its socket should never be allowed to become contaminated by handling. Such contamination produces leakage and dark current. It is recommended that if the tube base or its socket is handled that it be washed with a solution of alkaline cleanser and de-ionized or distilled water having a temperature not exceeding 60 degrees C. The base or the socket should then be rinsed in deionized or distilled water (<60 degrees C) for several minutes and then be air-blown dry.

Voltage Divider Considerations

Leads to all capacitors should be as short as possible to minimize inductance effects. The location and spacing of capacitors is critical and may require adjustment for optimum results. The capacitor values will depend upon the shape of the output pulse, the amplitude of the anode-current pulse, and the time duration of the pulse, or train of pulses. When the output pulse is assumed to be rectangular in shape, the following formula applies:

$$C = \frac{i(t)}{V} \times 100$$

where C is in farads
i is the amplitude of anode current in amperes
V is the voltage across the capacitor in volts
and t is the time duration of the pulse in seconds

This formula applies for the anode-to-final dynode capacitor. The factor 100 is used to limit the voltage change across the capacitor to 1% maximum during a pulse. Capacitor values for preceding stages should take into account the smaller values of dynode currents in these stages. Conservatively, a factor of 2 per stage is used. Capacitors are not required when the dynode current is less than 1/10 of the current through the voltage-divider network.

For other shaped pulses or for a train of pulses, the total charge q should be substituted for i(t) and the following formula applies:

$$C = \frac{q}{V} \times 100$$

where q = i(t) dt coulombs.

Warning - Personal Safety Hazards

Electrical Shock -- Operating voltages applied to this device present a shock hazard.

Table I

Voltage Distribution			
Between the Following Electrodes: Cathode (K), Dynode (Dy), and Anode (P)	**Column A*** 5.45% of K-P Voltage (E) Multiplied By:	**Column B** 8.06% of Dy1-P Voltage (E) Multiplied By:	**Column C*** 4.18% of K-P Voltage (E) Multiplied By:
K -- Dy1	6	**	6
Dy1 -- Dy2	1	1	1
Dy2 -- Dy3	1.4	1.4	1.4
Dy3 -- Dy4	1	1	1
Dy4 -- Dy5	1	1	1
Dy5 -- Dy6	1	1	1
Dy6 -- Dy7	1	1	1
Dy7 -- Dy8	1	1	1
Dy8 - Dy9	1	1	1
Dy9 -- Dy10	1	1	1.5
Dy10 -- Dy11	1	1	2
Dy11 -- Dy12	1	1	4
Dy12 -- P	1	1	2
Dy1 -- P	--	12.4	--
K -- p	18.4	--	23.9

Focusing Electrode is connected to arm of potentiometer between cathode and dynode no.1. The focusing-electrode voltage is varied to give maximum anode current. Multiplier shield is operated at dynode-no.5 potential.

** Cathode-to-dynode-no.1 voltage maintained at 660 volts.

* To take full advantage of the operating capabilities of the 8850 it is required that the cathode-to-dynode no.1 voltage be a minimum of 600 volts.

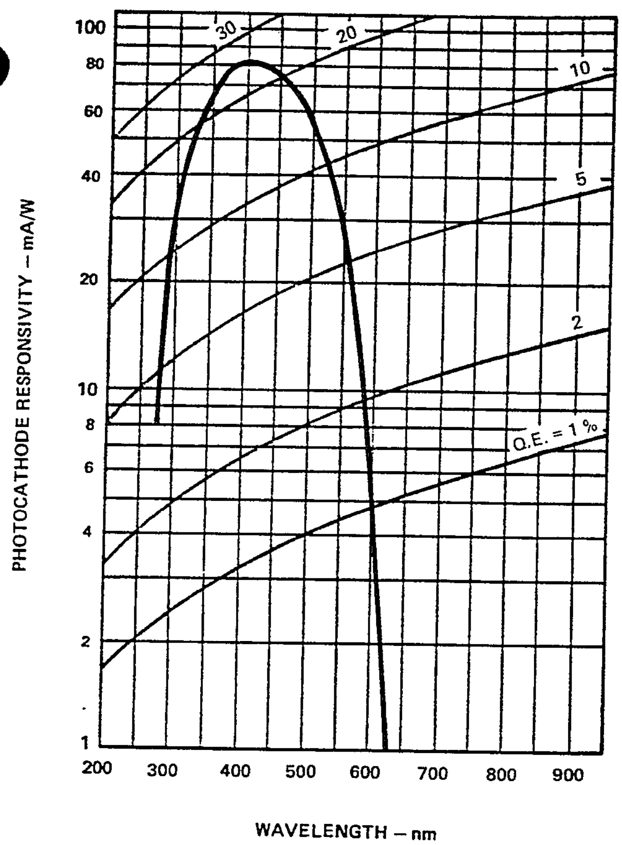


Figure 1 - Typical Photocathode Spectral Responsivity Characteristic

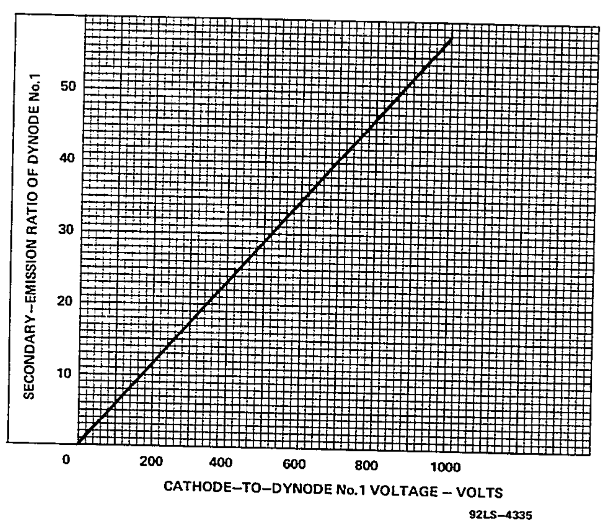


Figure 2 - Typical Secondary-Emission Ratio of First Dynode as a Function of Cathode-to-Dynode No.1 Voltage

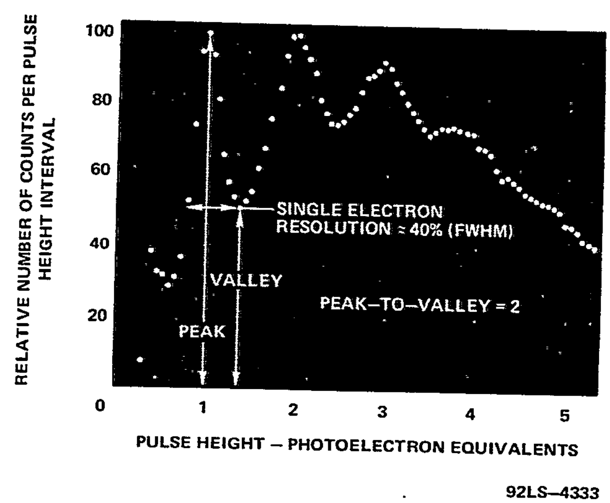


Figure 3 - Typical Photoelectron Pulse Height Spectrum

THE SUPPLY VOLTAGE (E) IS ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS:

BETWEEN:	5.45% OF E MULTIPLIED BY
CATHODE AND DYNODE No.1	6.0
DYNODE No.1 AND DYNODE No.2	1.0
DYNODE No.2 AND DYNODE No.3	1.4
EACH SUCCEEDING DYNODE-STAGE	1.0
ANODE AND CATHODE	18.4

FOCUSING ELECTRODE IS CONNECTED TO DYNODE-No.1 POTENTIAL.
ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-No.5 POTENTIAL.
PHOTOCATHODE IS FULLY ILLUMINATED.

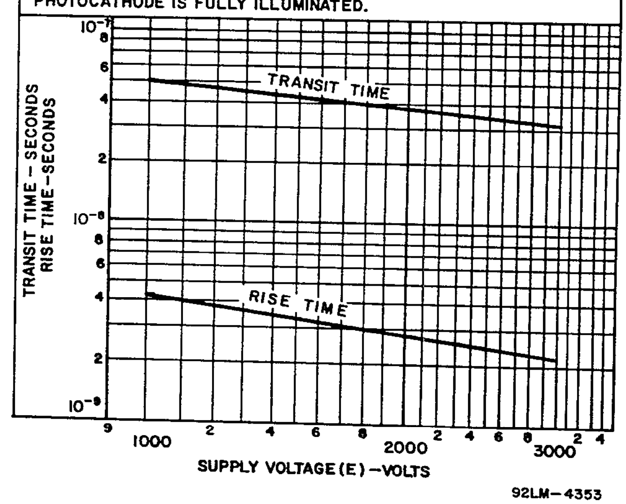


Figure 4 - Typical Time Resoplution Characteristics

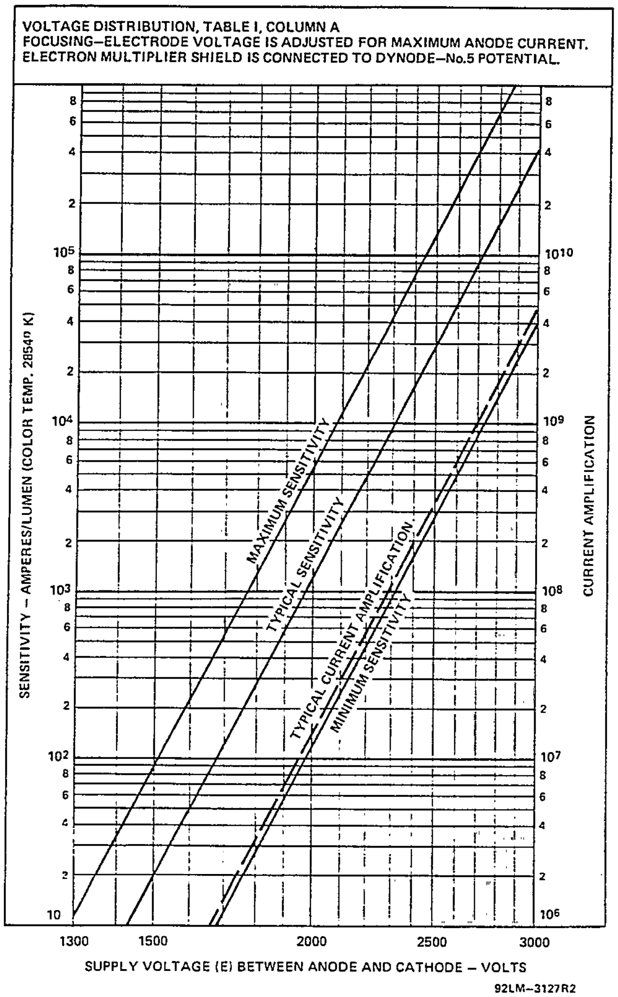


Figure 5 - Typical Sensitivity and Current Amplification Characteristics

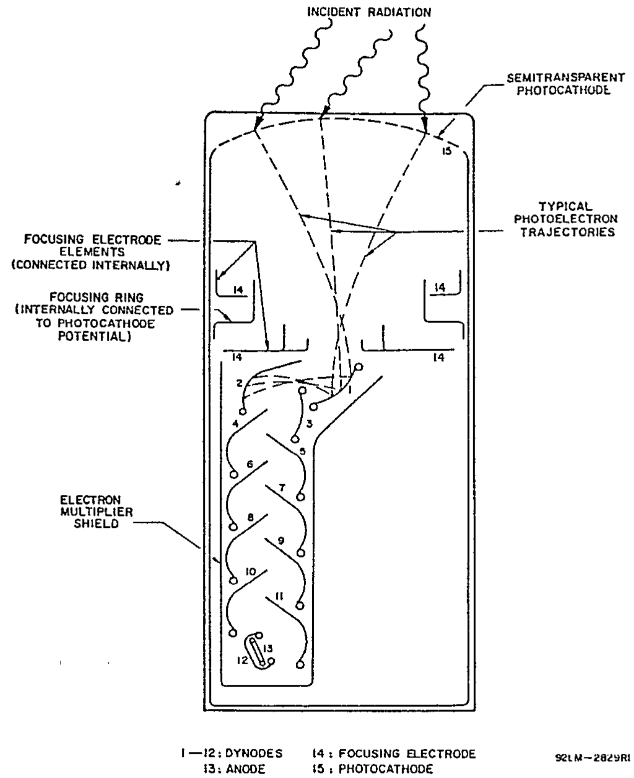


Figure 6 - Schematic Arrangement of Structure Showing Typical Electron Trajectories

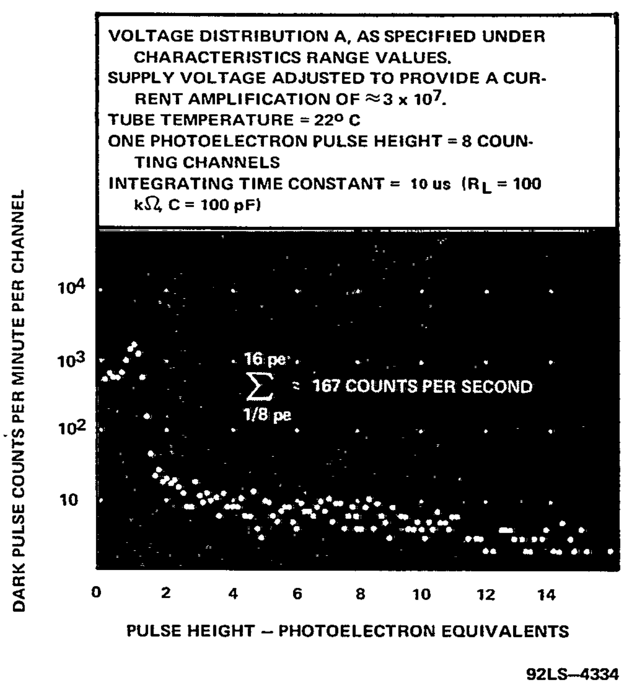


Figure 7 - Typical Dark Pulse Spectrum

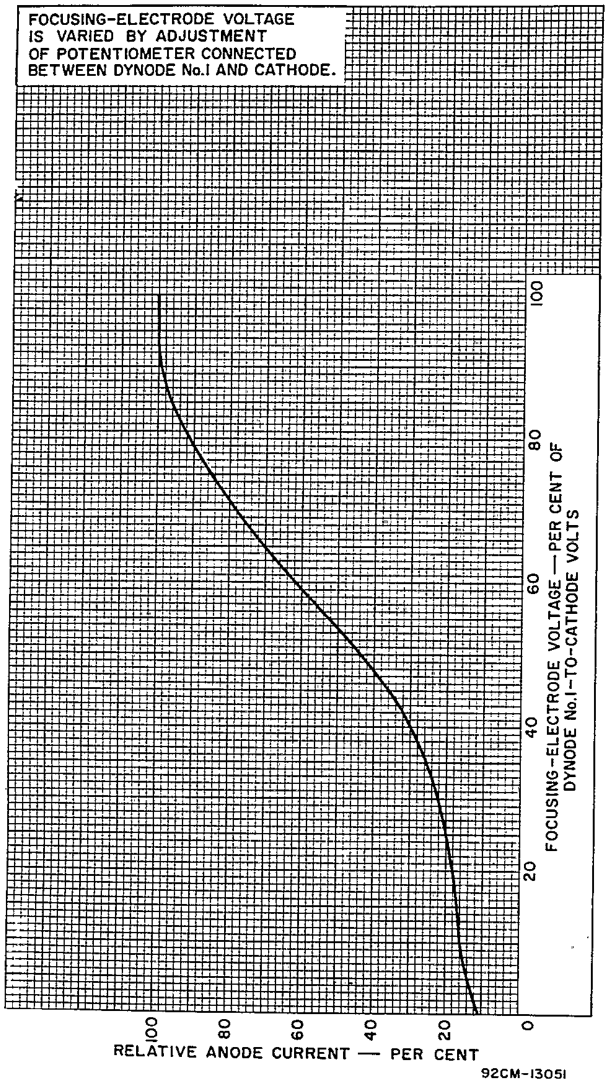


Figure 8 - Typical Focusing Electrode Characteristic

THE SUPPLY VOLTAGE (E) IS ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS:

BETWEEN:	5.45% OF E MULTIPLIED BY
CATHODE AND DYNODE No.1	6.0
DYNODE No.1 AND DYNODE No.2	1.0
DYNODE No.2 AND DYNODE No.3	1.4
EACH SUCCEEDING DYNODE STAGE	1.0
ANODE AND CATHODE	18.4

FOCUSING ELECTRODE IS CONNECTED TO DYNODE-No.1 POTENTIAL.
ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-No.5 POTENTIAL.
PHOTOCATHODE IS FULLY ILLUMINATED.

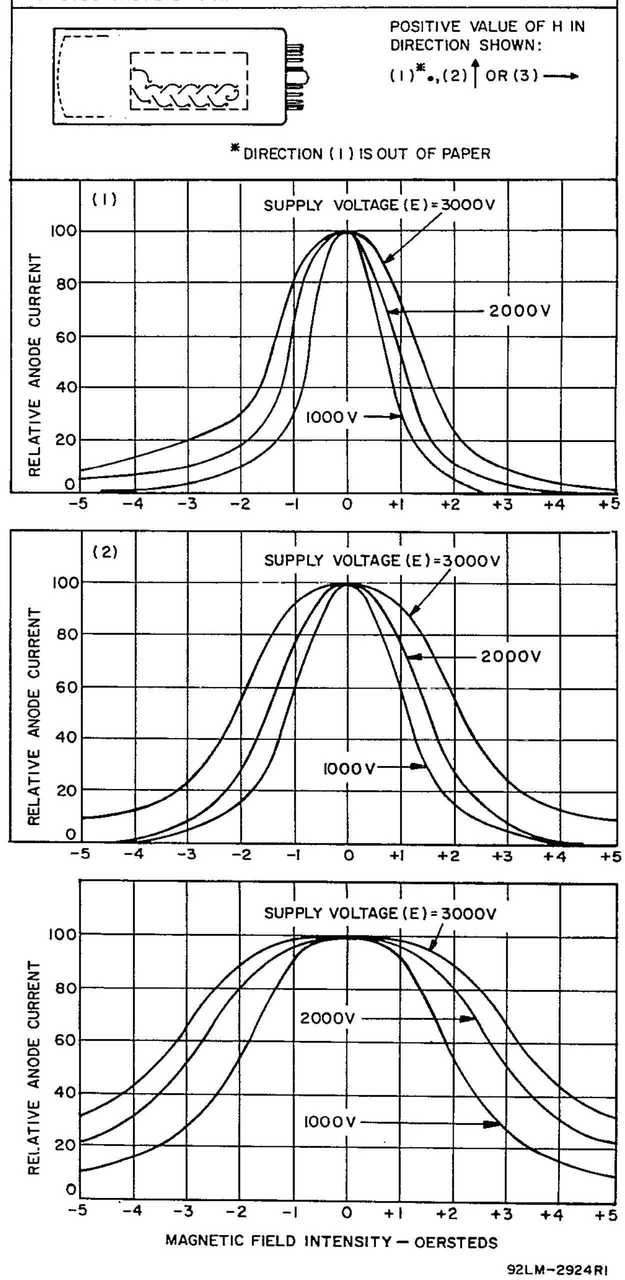


Figure 9 - Typical Effect of Magnetic Field on Anode Current

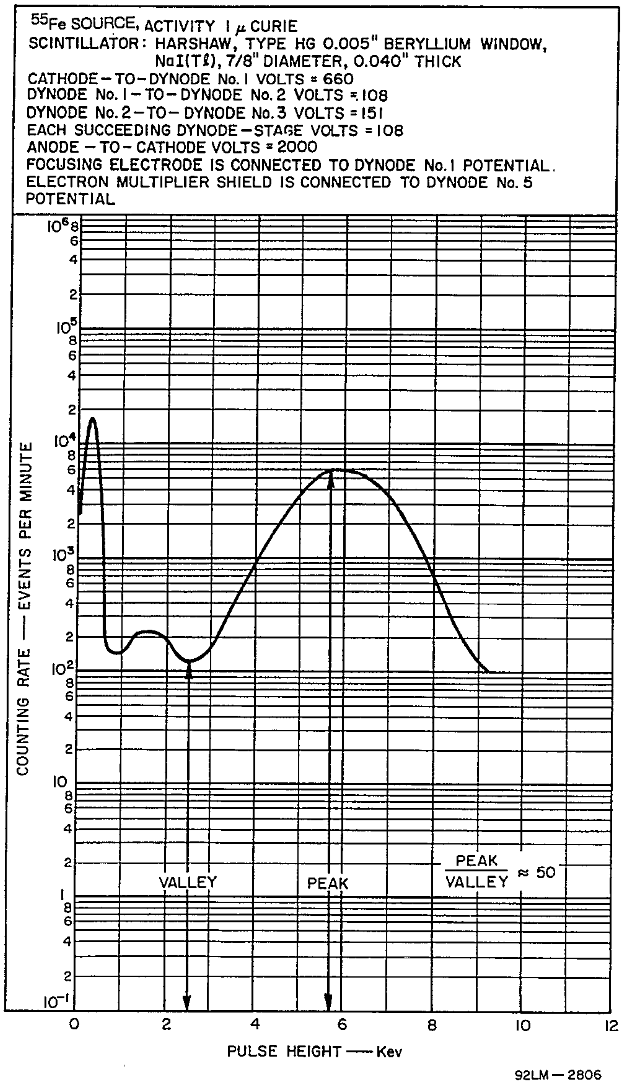


Figure 10 - Typical Differential ^{55}Fe Spectrum

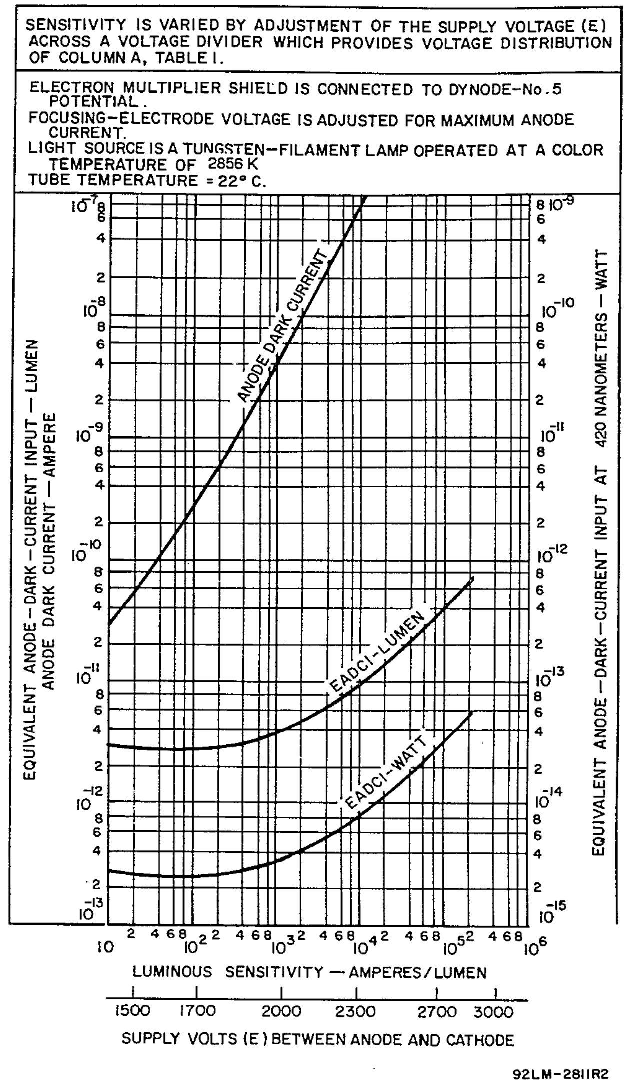


Figure 11 - Typical Anode Dark Current and EADCI Characteristics

THE SUPPLY VOLTAGE (E) IS ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS:

BETWEEN	5.45% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	6.0
DYNODE No. 1 AND DYNODE No. 2	1.0
DYNODE No. 2 AND DYNODE No. 3	1.4
EACH SUCCEEDING DYNODE STAGE	1.0
ANODE AND CATHODE	18.4

FOCUSING ELECTRODE IS CONNECTED TO DYNODE-No. 1 POTENTIAL.
ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-No. 5 POTENTIAL.
CATHODE IS AT GROUND POTENTIAL.

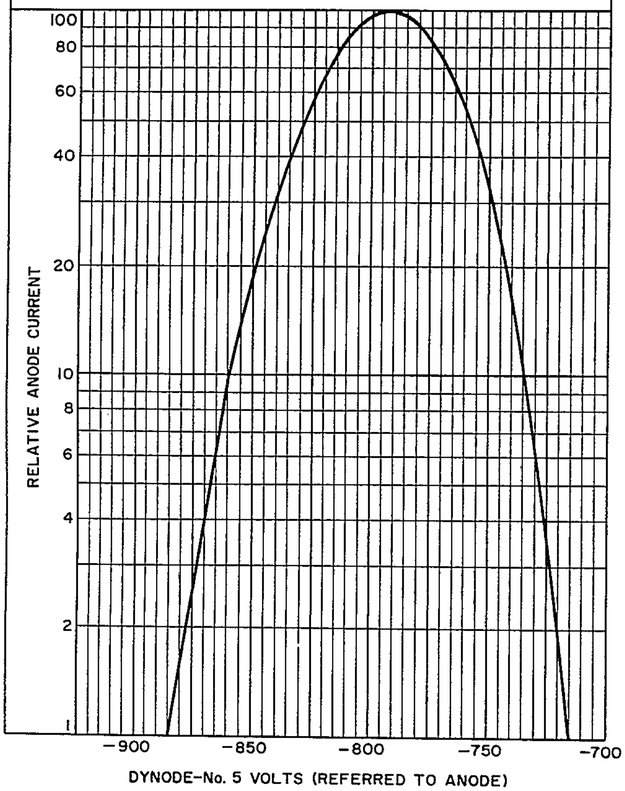
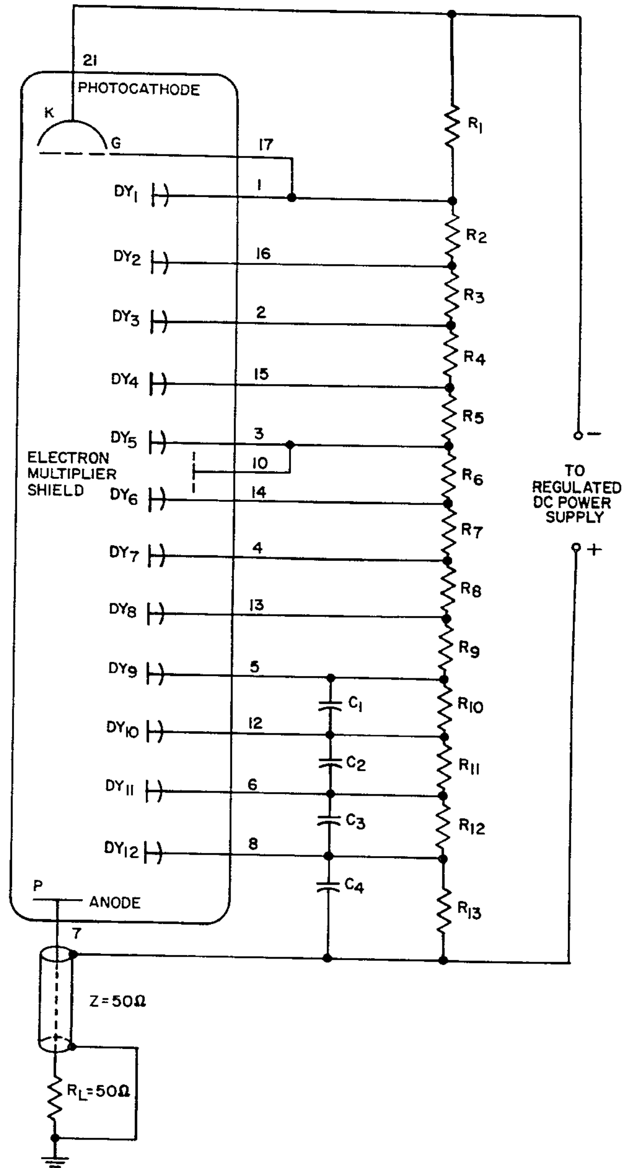


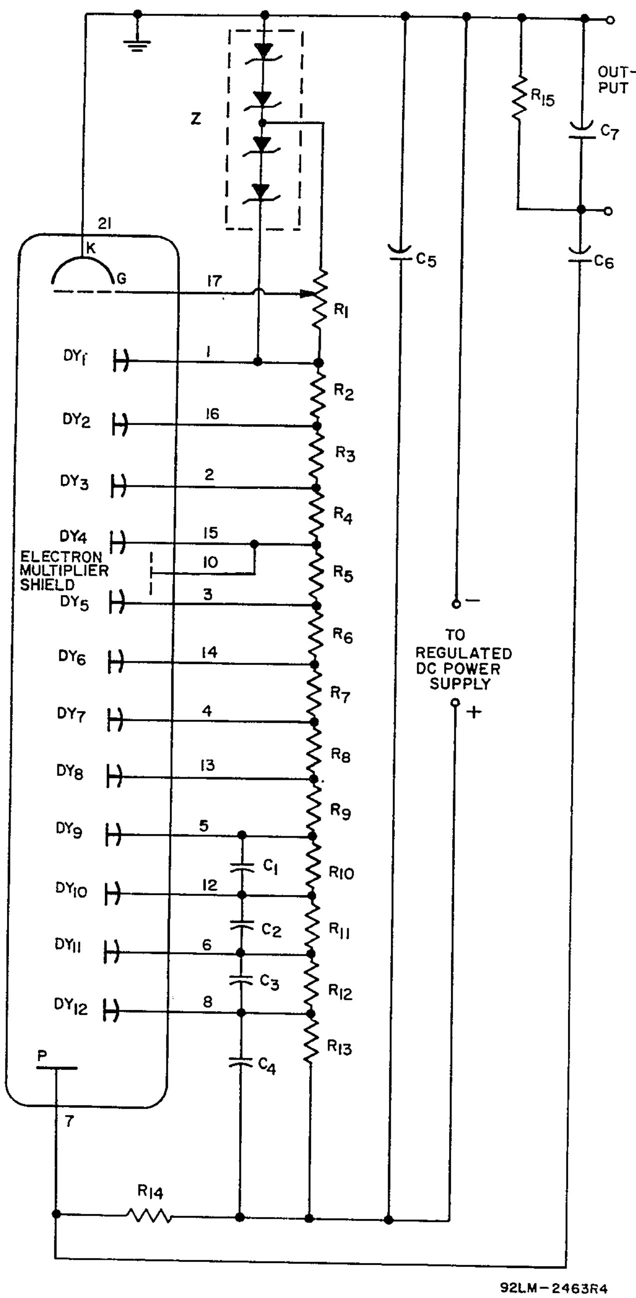
Figure 12 - Typical Dynode Modulation Characteristic



C1: 0.005 uF, 20%, Ceramic Disc, 500 VDC
C2: 0.01 uF, 20%, Ceramic Disc, 500 VDC
C3: 0.02 uF, 20%, Ceramic Disc, 500 VDC
C4: 0.05 uF, 20%, Ceramic Disc, 500 VDC
R1: 600 k ohm, (6-100 k ohm, 5%, 1 W in series)
R2: 100 k ohm, 5%, 1 W
R3: 130 k ohm, 5%, 1 W
R4 through R13: 100 k ohm, 5%, 1 Wa4968V

Note: Fast pulse response applications, to 3500 V (typical circuit values)

Figure 13 - Typical Circuit Arrangement for Fast Pulse Response



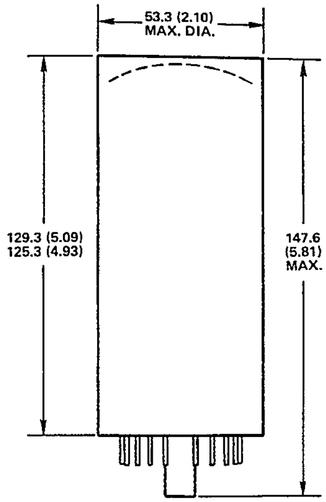
C1: 0.005 uF, 20%, Ceramic Disc, 500 VDC
C2: 0.01 uF, 20%, Ceramic Disc, 500 VDC
C3: 0.02 uF, 20%, Ceramic Disc, 500 VDC
C4: 0.05 uF, 20%, Ceramic Disc, 500 VDC
C5 and C6: 0.0047 uF, 20%, Ceramic Disc, 6000 VDC
R1: 10 M Ohm, 2 W, adjustable

For most applications the use of this potentiometer is unnecessary and it can be eliminated from the circuit. However, when it is desired to optimize transit time dispersion or current amplification, the potentiometer should be used.

R2, R4 thorugh R13: 510 k ohm, 5%, 1/2 W
R3: 750 k ohm, 5%, 1/2 W
R14: 1 M ohm, 5%, 1/2W
Z: (2) -- 150 V, 400 mW zener diodes, or equivalent
(2) -- 180V, 400 mW zener diodes, or equivalent

Note: The value of the load elements R15 and C7 depend on the application. For most applications, R15 x C7 = 10 microseconds. It is to be noted that R14 is in parallel with R15 and must be considered when selecting the value.

Figure 14 - Typical Circuit Arrangement for Scintillation Counting Applications



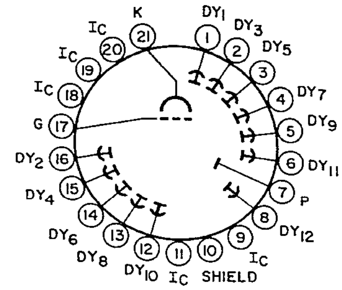
Dimensions are in millimeters unless otherwise stated. Dimensions in parentheses are in inches.

Note 1 - Minimum useful area of photocathode is 16.4 cm^2 (2.54 in^2). Useful photocathode diameter is 45.7 mm (1.80 in).

Note 2 -Deviation from flatness of external surface of faceplate will not exceed 0.25 mm (0.010") from peak to valley. Faceplate material is pyrex (Corning No.7740), or equivalent. Its index of refraction at 589.3 nm is 1.47.

Note 3 - Typical sockets for this base are BURLE AJ2144A and AJ2145A.
The AJ2145A is ordinarily supplied with the tube and is designed specifically for chassis mounting. The AJ2144A is designed for use in any desired mounting arrangement. It is suppliedwith an unattached clamp ring which fits to either the top or bottom of its socket body to permit chassis mounting. The ring is not normally required for other mounting arrangements and can be discarded to make such arrangements more compact.

Note 4 - Magnetic shielding of the tube is ordinarily required. A typical shield is the BURLE AJ2252.



DIRECTION OF RADIATION:
INTO END OF BULB

92LS-2812

Pin 1: Dynode No.1
Pin 2: Dynode No.3
Pin 3: Dynode No.5
Pin 4: Dynode No.7
Pin 5: Dynode No.9
Pin 6: Dynode No.11
Pin 7: Anode
Pin 8: Dynode No.12
Pin 9: Internal Connection, Do Not Use
Pin 10: Electron Multiplier Shield
Pin 11: Internal Connection, Do Not Use
Pin 12: Dynode No.10
Pin 13: Dynode No.8
Pin 14: Dynode No.6
Pin 15: Dynode no.4
Pin 16: Dynode No.2
Pin 17: Focusing Electrode
Pin 18: Internal Connection, Do Not Use
Pin 19: Internal Connection, Do Not Use
Pin 20: Internal Connection, Do Not Use
Pin 21: Photocathode

Figure 15 - Dimensional Outline and Basing Diagram