

# Photomultiplier Tube

5-Inch Diameter, 14-Stage, Head-On Type  
 High Quantum Efficiency Bi-alkali Photocathode  
 In-Line Electrostatically-Focused Dynode Structure

For Use in Nuclear Physics Applications, Especially  
 When a High Degree of Time Definition is Required

## GENERAL

Spectral Response	See accompanying <i>Typical Spectral Response Characteristics</i>
Wavelength of Maximum Response	4000 ± 500 Å
Cathode, Semitransparent	Cs-K-Sb(Bi-alkali)
Shape	Spherical Section
Minimum projected area	16 sq. in (103 sq. cm)
Minimum diameter	4.5 in (11.4 cm)
Window	UV-transmitting, Corning <sup>a</sup> No.9741, or Equivalent
Shape	Spherical Section
Index of refraction at 4047 angstroms	1.48
Dynodes:	
Substrate	Copper-Beryllium
Secondary-Emitting Surface	Beryllium-Oxide
Structure	In-Line Electrostatic-Focus
Direct Interelectrode Capacitances (Approx.):	
Anode to dynode No.14	5.5 pF
Anode to all other electrodes	7.0 pF
Maximum Overall Length	12 in (30.5 cm)
Maximum Diameter	5.25 in (13.3 cm)
Base	See Base Drawing
Socket	RCA-AJ2144 or AJ2145
Magnetic Shield	See Note (b)
Operating Position	Any
Weight (Approx.)	21 oz (590 g)

## MAXIMUM AND MINIMUM RATINGS, Absolute-Maximum Values

### DC Supply Voltage:

Between anode and cathode:

With Voltage Distribution

A or B, shown in Table I . . . . . 3000 max. V

With Voltage Distribution

C, shown in Table I . . . . . 3500 max. V

Between anode and dynode No.14 . . . . . 600 max. V

Between dynode No.14 & dynode No.13 . . . . . 800 max. V

Between other consecutive dynodes. . . . . 400 max. V

Between dynode No.1

and cathode . . . . . { 800 max. V

{ 300 min. V

Average Anode Current<sup>d</sup> . . . . . 0.5 max. mA

Ambient-Temperature Range . . . . . -100 to +85 °C

## CHARACTERISTICS RANGE VALUES

	Min.	Typ.	Max.	
<b>With a DC Supply Voltage (E) = 2000 volts (Except as noted)</b>				
<i>Voltage Distribution A, Table I</i>				
Anode Sensitivity:				
Radiant <sup>e</sup> at 4000 Å <sup>c</sup> . . .	-	2.6 x 10 <sup>6</sup>	-	A/W
Luminous <sup>f</sup> (2870°K) . . .	6.5 x 10 <sup>2</sup>	2.3 x 10 <sup>3</sup>	6.5 x 10 <sup>3</sup>	A/lm
With blue light source <sup>g</sup> (2870°K + C.S. No.5-58) . . .				
	8.5 x 10 <sup>-6</sup>	3 x 10 <sup>-5</sup>	8.5 x 10 <sup>-5</sup>	A
Cathode Sensitivity:				
Radiant <sup>h</sup> at 4000 Å . . .	-	8.8 x 10 <sup>-2</sup>	-	Δ/W
Luminous <sup>i</sup> (2870°K) . . .	-	7.7 x 10 <sup>-5</sup>	-	A/lm
With blue light source <sup>k</sup> (2870°K + C.S. No.5-58) . . . . .				
	8 x 10 <sup>-10</sup>	1 x 10 <sup>-9</sup>	-	A
Cathode Quantum Efficiency at 3600 Å . . . . .				
	-	29	-	%
Current Amplification . . .	-	3 x 10 <sup>7</sup>	-	
Anode Dark Current <sup>m</sup> . . .	-	6 x 10 <sup>-8</sup>	1 x 10 <sup>-6</sup>	A
Equivalent Anode Dark Current Input . . .				
	{	3 x 10 <sup>-11n</sup>	5 x 10 <sup>-10n</sup>	lm
		2.6 x 10 <sup>-14p</sup>	-	W
<b>With E = 2500 volts</b>				
<i>Voltage Distribution B, Table I</i>				
Pulse Height Resolution <sup>q</sup>	-	7.5	-	%
Mean Gain Deviation <sup>r</sup> . . .	-	1	-	%
Dark Pulse Spectrum . . .		See <i>Typical Dark Pulse Spectrum</i>		
<b>With E = 3000 volts</b>				
<i>Voltage Distribution A, Table I</i>				
Anode-Pulse Rise Time . . .	-	2.9 x 10 <sup>-9</sup>	-	s
Electron Transit Time . . .	-	6.6 x 10 <sup>-8</sup>	-	s
<b>With E = 3000 volts</b>				
<i>Voltage Distribution C, Table I</i>				
Pulse Current: <sup>u</sup>				
Linear <sup>v</sup> . . . . .	-	0.13	-	A
Saturated . . . . .	-	0.32	-	A

- a Made by Corning Glass Works, Corning, New York 14830.
- b Magnetic shielding is available from manufacturers such as the Magnetic Shield Division, Perfection Mica Co., 1322 North Elston, Chicago 22, Illinois.
- d Averaged over any 500-microsecond interval.
- e This value is calculated from the typical anode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.

- f These values are calculated as shown below:

$$\frac{\text{Luminous Sensitivity (A/lm)} = \text{Anode Current (with blue light source) (A)}}{0.13 \times \text{Light Flux of } 1 \times 10^{-7} \text{ (lm)}}$$

The value of 0.13 is an average value. It is the ratio of the cathode current measured under the conditions specified in footnote (k) to the cathode current measured under the same conditions but with the blue filter removed.

- g Light incident on the cathode 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 2870° K. The value of light flux incident on the filter is 0.1 microlumen.
- h This value is calculated from the typical cathode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.
- i These values are calculated as shown below:

$$\frac{\text{Cathode Luminous Sensitivity (A/lm)} = \text{Cathode Current (with blue light source) (A)}}{0.13 \times \text{Light Flux of } 1 \times 10^{-4} \text{ (lm)}}$$

The value of 0.13 is an average value. (See footnote f).

- k Light incident on the cathode 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 2870° K. The value of light flux incident on the filter is 100 microlumens and 300 volts are applied between cathode and all other electrodes connected as anode.
- m At a tube temperature of 22° C. Light incident on the cathode 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 0.1 microlumen. The supply voltage E is adjusted to obtain an anode current of 26 microamperes. Luminous sensitivity of the tube under these conditions is approximately equivalent to 2000 amperes per lumen. Dark current is measured with incident light removed.

- <sup>n</sup> With supply voltage E adjusted to give a calculated value of anode luminous sensitivity of 2000 amperes per lumen.
- <sup>p</sup> At 4000 Å. Calculated from the luminous EADCI value using a conversion factor of 1140 lumens per watt.
- <sup>q</sup> With a supply voltage E of 2500 volts across a voltage divider providing electrode voltages shown in Table I, Distribution B. Anode load is a 10-kilohm resistor in parallel with a total capacitance of 1000 pF. Under pulse conditions, the interstage voltages of the tube should not deviate more than 2% from the interstage voltage values during no-signal conditions. 662 keV photons from a one-microcurie Cs<sup>137</sup> source and a cylindrical 5" dia. x 4" thallium-activated sodium-iodide scintillator NaI (TI)-type Harshaw<sup>■</sup> 20A16, Serial No. CW-675 or equivalent are used. The Cs<sup>137</sup> source is in direct contact with the metal end of the scintillator container. The faceplate end of the crystal is coupled to the faceplate adapter (RCA-AJ2142) by an optical coupling material such as Dow Corning\* \*20-057.
- <sup>r</sup> Under the same conditions as shown in (q) except the tube is operated for a period of 1 hour with the radiation source located at the point providing a pulse count rate of 1000 counts per second. Following this time interval, the pulse height is sampled at 1-hour intervals for a period of 24 hours.
- <sup>u</sup> Using a pulsed light source having a pulse duration of 0.5 microsecond and repetition rate of 30 pulses per second. The interstage voltages of the tube should not deviate more than 2 per cent from the recommended voltage distribution shown by Voltage Distribution C of Table I. Capacitors are connected across the individual resistors making up the voltage-divider arrangement to insure this operating condition.
- <sup>v</sup> Maximum deviation from linearity is 5 per cent.

<sup>■</sup>Made by Harshaw Chemical Corporation, 1945 East 97 Street, Cleveland 6, Ohio.

\*Made by Dow Corning Corp., Midland, Michigan.

#### OPERATING CONSIDERATIONS

The base pins of the tube fit a 21-contact socket such as the RCA-AJ2144 and AJ2145. The 4522 can replace types 58AVP and 580VP by use of Socket Adapter, RCA-AJ2143.

The operating stability of the 4522 is dependent on the magnitude of the average anode current.

The use of an average anode current well below the

the maximum rated value of 500 microamperes is recommended when stability of operation is important. When maximum stability is required, the average anode current should not exceed 0.1 microampere.

Magnetic shielding of the tube is generally required. Magnetic shielding materials are available from manufacturers such as the Magnetic Shield Division, Perfection Mica Company, 1322 North Elston, Chicago 22, Illinois. The curves under *Typical Voltage-Divider arrangements* show the effect of magnetic fields on anode current under the conditions indicated. With increase in voltage between anode and cathode, the effect of a given magnetic field will cause less decrease in anode current.

The high voltages at which the tube is operated are very dangerous. Care should be taken in the design of apparatus to prevent personnel from coming in contact with these high voltages. Precautions should include the enclosure of high-voltage terminals and the use of interlock switches to break the primary circuit of the high-voltage power supply when access to the apparatus is required.

*Accompanying typical voltage-divider arrangements* are recommended for use with the 4522. The choice of resistance values for the voltage-divider string is usually a compromise. If low values of resistance per stage are utilized, the power drawn from the supply and the required wattage rating of the resistors increase. Phototube noise may also increase, due to heating, if the divider network is mounted near the tube. The use of high values of resistance per stage may cause deviation from linearity if the voltage-divider current is not maintained at a value of at least 10 times that of the maximum average anode current and may limit anode current response to pulsed light.

The supply voltage may be applied in 500-volt steps up to 2000 volts, and 200-volt steps from 2000 to 3000

# 4522

volts and with no less than 1 minute between each step.

## OPERATING VOLTAGES

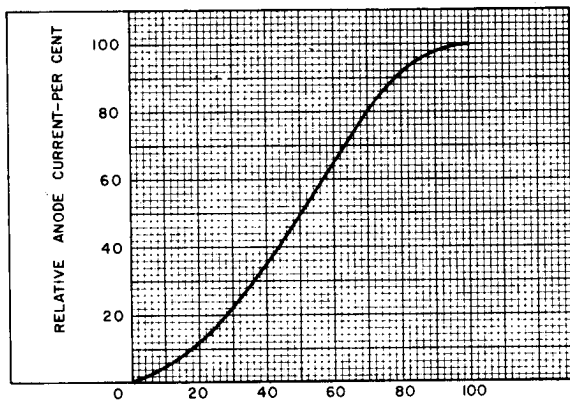
Table I shows three electrode voltage distributions recommended for the 4522.

Voltage Distribution A is used to measure the tube performance values listed under *Characteristic Range Values* and is suggested for general purpose applications.

Voltage Distribution B is recommended where high dynode-No.1 gain is important, such as in low light level and scintillation counting applications. Voltage Distribution B maintains the cathode-to-dynode-No.1 voltage at 660 volts; it is especially useful when the supply voltage is adjusted over a wide range to achieve large changes in anode sensitivity. A suggested circuit using voltage distribution B is shown under *Typical Circuit Arrangement for Scintillation-Counting Applications*.

Voltage Distribution C is recommended for high peak-pulse current applications.

## TYPICAL FOCUSING ELECTRODE CHARACTERISTIC



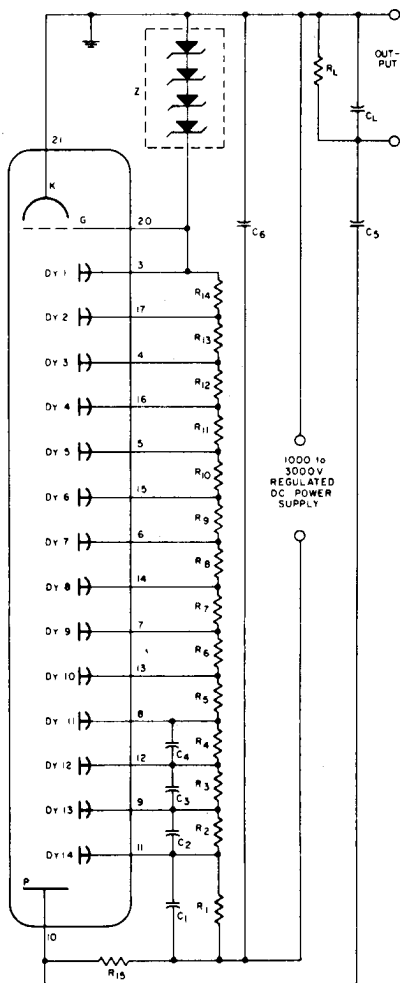
FOCUSING ELECTRODE VOLTAGE —  
PER CENT OF CATHODE-TO-DYNODE No.1 VOLTAGE

92L5-247IRI

TABLE I

Voltage Distribution			
Between the following Electrodes: Cathode (K), Dynode (Dy), and Anode (P)	A	B <sup>●</sup>	C
	5.9% of K-P Voltage (E) Multiplied by:	6.9% of Dy1-P Voltage (E) Multiplied by:	3.85% of K-P Voltage (E) Multiplied by:
K - Dy1	3	4	6
Dy1 - Dy2	1	1	1
Dy2 - Dy3	1	1.5	1.5
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
Dy10 - Dy11	1	1	1
Dy11 - Dy12	1	1	1.5
Dy12 - Dy13	1	1	2
Dy13 - Dy14	1	1	4
Dy14 - P	1	1	2
Dy1 - P	—	14.5	—
K - P	17	—	26
Focusing electrode <sup>▲</sup> is connected to Dynode-No.1 voltage.			
<ul style="list-style-type: none"> <li>● Use distribution B for optimum pulse-height resolution performance. See <i>Operating Voltages</i>.</li> <li>● Cathode-to-Dynode-No.1 Voltage maintained at 660 volts.</li> <li>▲ Focusing electrode may be connected to arm of potentiometer between cathode and dynode No.1; the focusing-electrode voltage is varied to give maximum anode current.</li> </ul>			

TYPICAL CIRCUIT ARRANGEMENT FOR FAST PULSE  
RESPONSE AND HIGH PEAK CURRENT APPLICATIONS



92LM-2463R



## PARTS LIST FOR TYPICAL CIRCUIT ARRANGEMENTS FOR SCINTILLATION COUNTING APPLICATIONS

- $C_1$ : 0.05  $\mu\text{F}$ , 20%, 500 V dc Ceramic-Disc Type  
 $C_2$ : 0.02  $\mu\text{F}$ , 20%, 500 V dc Ceramic-Disc Type  
 $C_3$ : 0.01  $\mu\text{F}$ , 20%, 500 V dc Ceramic-Disc Type  
 $C_4$ : 0.005  $\mu\text{F}$ , 20%, 500 V dc Ceramic-Disc Type  
 $C_5$  &  $C_6$ : 0.0047  $\mu\text{F}$ , 20%, 6000 V dc Ceramic-Disc Type  
 $R_1$  through  $R_{12}$ : 51  $\text{K}\Omega$ , 5% 1W  
 $R_{13}$ : 75  $\text{K}\Omega$ , 5% 1W  
 $R_{14}$ : 51  $\text{K}\Omega$ , 5% 1W  
 $R_{15}$ : 100  $\text{K}\Omega$ , 5% 1/2 W  
 $Z$ : (2)-150 V, 1W zener diodes, or equivalent  
(2)-180 V, 1W zener diodes, or equivalent

**Note:** The value of the load elements,  $R_L$  and  $C_L$ , depend on the application:

$$R_L C_L = 10 \text{ microseconds for most applications}$$

## PARTS LIST FOR TYPICAL CIRCUIT ARRANGEMENT FOR FAST PULSE RESPONSE AND HIGH PEAK CURRENT APPLICATIONS

### Fast Pulse Response Applications, to 3000V

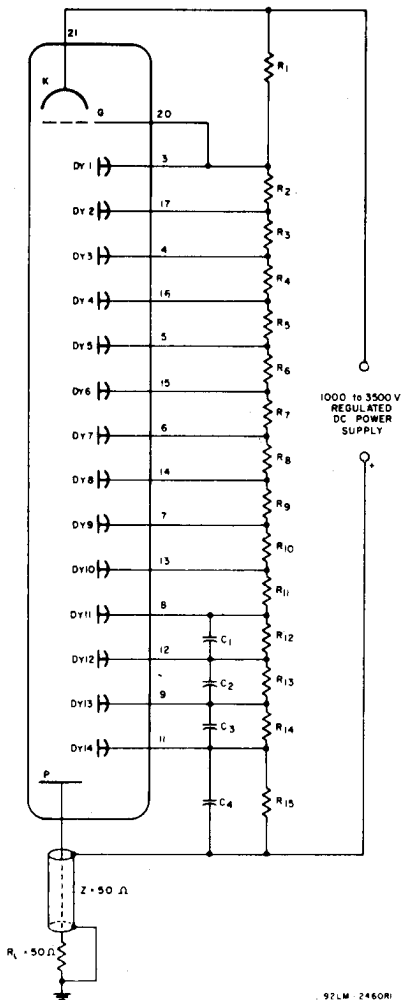
- $C_1$ : 0.005  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $C_2$ : 0.01  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $C_3$ : 0.02  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $C_4$ : 0.05  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $R_1$ : 300  $\text{K}\Omega$  (3-100  $\text{K}\Omega$ , 5%, 1/2 W in series)  
 $R_2$  through  $R_{15}$ : 100  $\text{K}\Omega$ , 5%, 1/2 W

### High Peak Current Applications, to 3500V

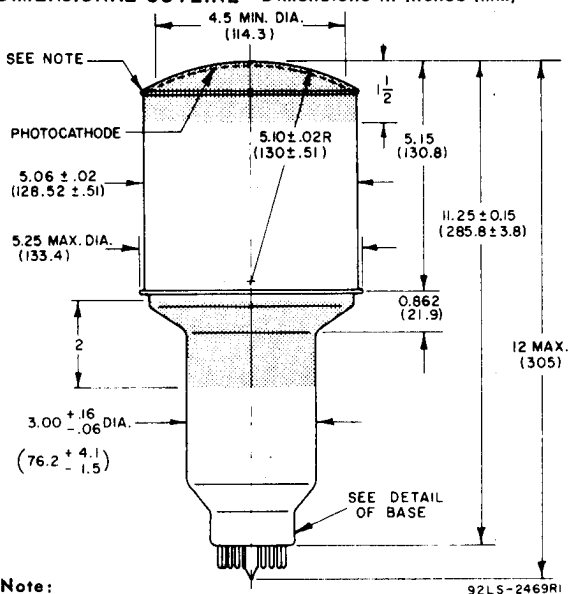
- $C_1$ : 0.005  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $C_2$ : 0.01  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $C_3$ : 0.02  $\mu\text{F}$ , Ceramic Disc, 1000 V  
 $C_4$ : 0.05  $\mu\text{F}$ , Ceramic Disc, 500 V  
 $R_1$ : 168  $\text{K}\Omega$  (3-56  $\text{K}\Omega$ , 5%, 2 W, in series)  
 $R_2, R_4$  through  $R_{11}$ : 27  $\text{K}\Omega$ , 5%, 1 W  
 $R_3, R_{12}$ : 39  $\text{K}\Omega$ , 5%, 2 W  
 $R_{13}, R_{15}$ : 54  $\text{K}\Omega$  (2-27  $\text{K}\Omega$ , 5%, 1 W, in series)  
 $R_{14}$ : 108  $\text{K}\Omega$  (4-27  $\text{K}\Omega$ , 5%, 1 W, in series)

**Note:** Leads to all capacitors should be as short as possible to minimize inductance effects. Location and spacing of capacitors is critical and may require adjustment for optimum results.

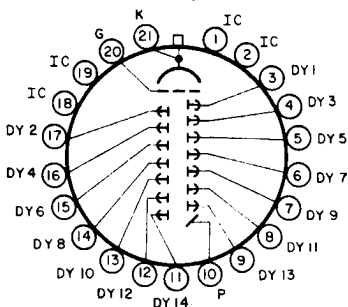
TYPICAL CIRCUIT ARRANGEMENT FOR FAST PULSE  
RESPONSE AND HIGH PEAK CURRENT APPLICATIONS



## DIMENSIONAL OUTLINE - Dimensions in Inches (mm)

**Note:**

Care must be taken in mounting the tube so that the tube envelope is not subjected to excessive pressure which could strip the glass-to-metal seals. In no case should mounting supports be used in the shaded areas.

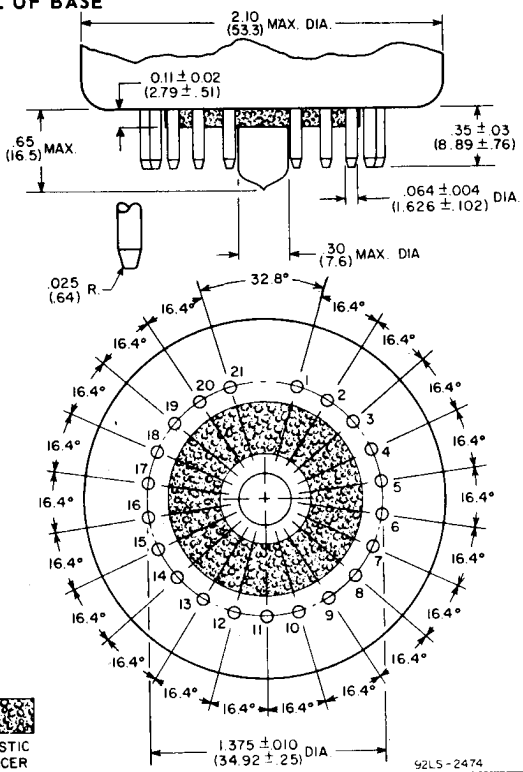
**BASING DIAGRAM (Bottom View)**

92LS-1258R1

Pin No. 1: Internally connected— Do not use.  
 Pin No. 2: Internally connected— Do not use.  
 Pin No. 3: Dynode No.1  
 Pin No. 4: Dynode No.3  
 Pin No. 5: Dynode No.5  
 Pin No. 6: Dynode No.7  
 Pin No. 7: Dynode No.9  
 Pin No. 8: Dynode No.11  
 Pin No. 9: Dynode No.13  
 Pin No.10: Anode  
 Pin No.11: Dynode No.14

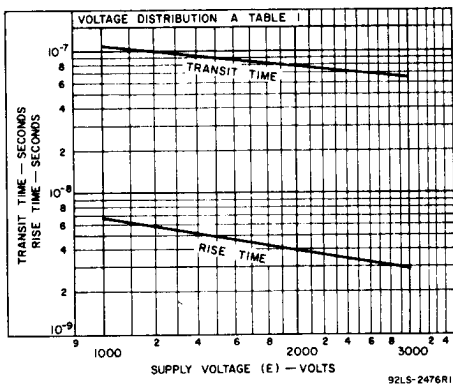
Pin No.12: Dynode No.12  
 Pin No.13: Dynode No.10  
 Pin No.14: Dynode No.8  
 Pin No.15: Dynode No.6  
 Pin No.16: Dynode No.4  
 Pin No.17: Dynode No.2  
 Pin No.18: Internally connected— Do not use.  
 Pin No.19: Internally connected— Do not use.  
 Pin No.20: Focusing Electrode  
 Pin No.21: Photocathode and Tube Envelope

## DETAIL OF BASE

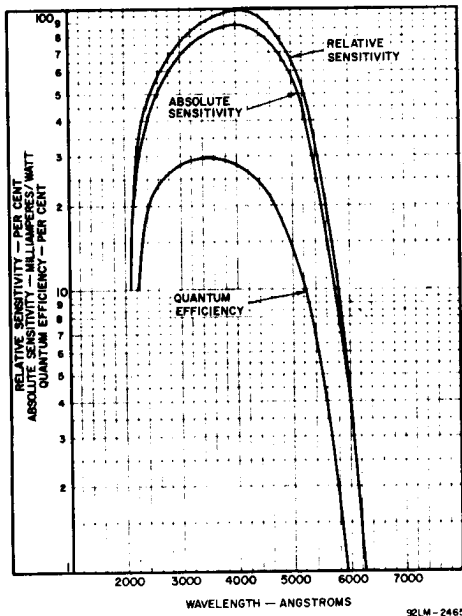


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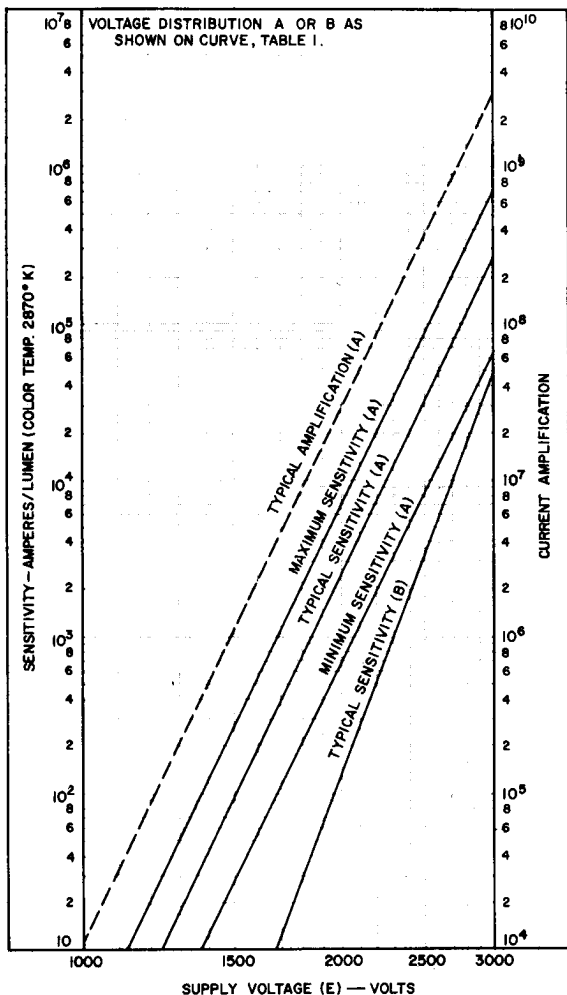
## TYPICAL TIME RESOLUTION CHARACTERISTICS



## TYPICAL SPECTRAL RESPONSE CHARACTERISTICS

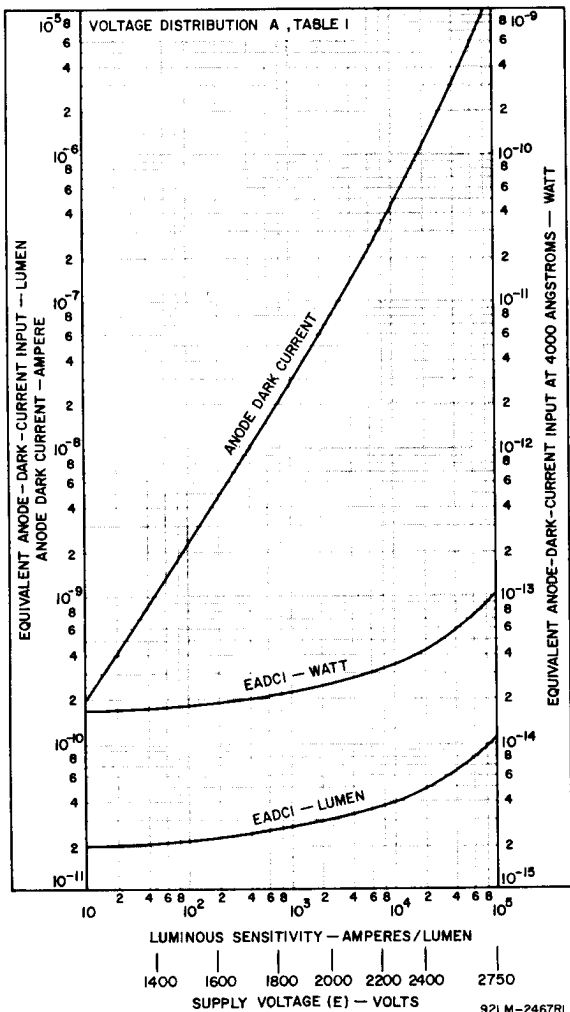


### SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS

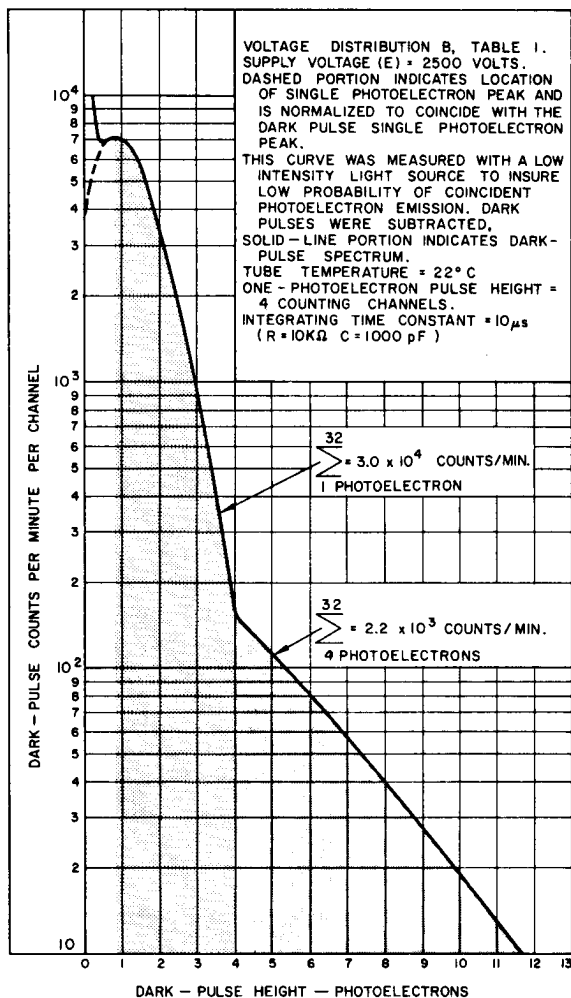


92LM-2466RI

# TYPICAL EADCI AND ANODE DARK CURRENT CHARACTERISTICS



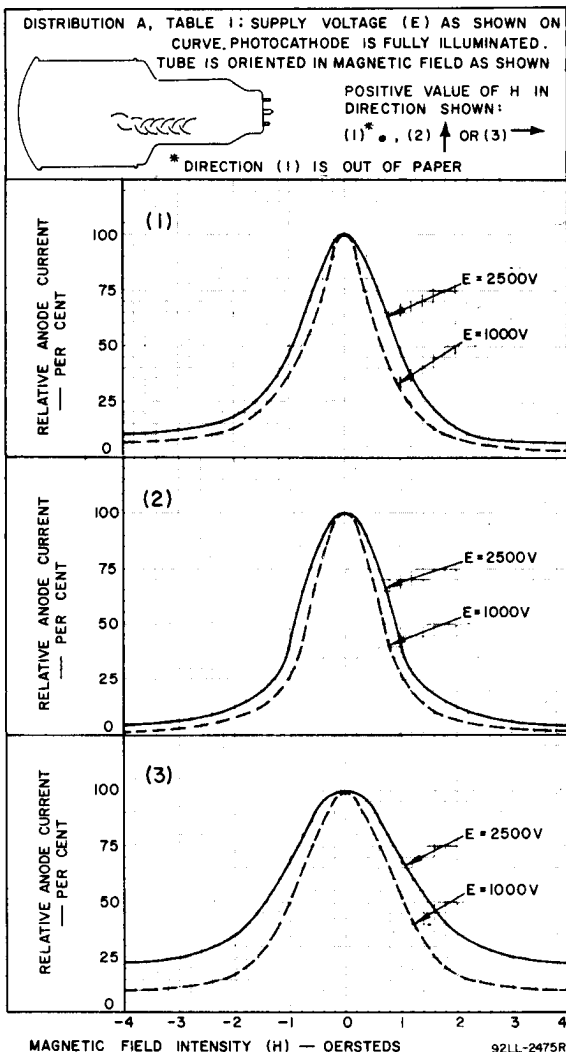
## TYPICAL DARK-PULSE SPECTRUM



92LM-2472R1



# TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT



## TYPICAL ANODE CHARACTERISTICS

