Photomultiplier Tube

3"-Diameter, 10-Stage, Venetian-Blind Type Having a Bialkali Photocathode and Aluminum-Oxide Window

GENERAL

Spectral Response	See Accompanying *Typical Spectral Response Characteristics*
Wavelength of Maximum Response	4000 ± 500 Å
Cathode, Semitransparent	Potassium-Cesium-Antimony (Bialkali)
Minimum area	5.27 in^2 (34.1 cm^2)
Minimum diameter	2.59 in (6.6 cm)
Window	Aluminum Oxide
Shape	Plano-Plano
Index of refraction at 4100 angstroms	1.78
Dynodes:	
Substrate	Copper-Beryllium
Secondary-Emitting Surface	Beryllium-Oxide
Structure	Venetian-Blind
Direct Interelectrode Capacitances (Approx.):	
Anode to dynode No.10	3.3 pF
Anode to all other electrodes	8.9 pF
Maximum Overall Length	5.86 in (14.8 cm)
Maximum Diameter	3.055 in (7.75 cm)
Bulb	See Dimensional Outline
Base (Temporary)	Small-Shell Diheptal 14-Pin (JEDEC Group 5, No.B14-45)
Socket	Cinch[a] No.3M14, or equivalent
Magnetic Shield	See Footnote b
Operating Position	Any
Weight (Approx.)	10.6 oz (300 g)

MAXIMUM RATINGS, Absolute-Maximum Values:

DC Supply Voltage:		
Between anode and cathode	2000 max.	V
Between anode and dynode No.10	300 max.	V
Between consecutive dynodes	250 max.	V
Between dynode No.1 and cathode	600 max.	V
Between focusing electrode and cathode	600 max.	V
Average Anode Current[d]	0.5 max.	mA
Ambient-Temperature Range[e]	-100 to +85	°C

CHARACTERISTICS RANGE VALUES

Under conditions with dc supply voltage (E) across a voltage divider providing the electrode voltages shown in Table I, except as noted, and at a temperature of 22° C.

With E = 1500 volts (Except as noted)

	Min.	Typical	Max.	
Anode Sensitivity:				
Radiant[f] at 4000 angstroms	–	1.9×10^{4}	–	A/W
Luminous[g] (2870° K)	7.5	18	165	A/lm
Current with blue light source[h] (2870° K + C.S. No.5-58)	9×10^{-6}	2.2×10^{-5}	2×10^{-4}	A
Cathode Sensitivity:				
Radiant[i] at 4000 angstroms	–	0.087	–	A/lm
Luminous[k] (2870° K)	6.7×10^{-5}	8.3×10^{-5}	–	A/lm
Current with blue light source[m] (2870° K + C.S. No.5-58)	8×10^{-10}	1×10^{-9}	–	A
Quantum Efficiency at 4000 angstroms	–	27	–	%
Current Amplification	–	2.2×10^{5}	–	
Anode Dark Current[n]	–	2×10^{-9}	6×10^{-9}	A
Equivalent Anode Dark Current Input[n]	–	2.7×10^{-10}	8×10^{-10}	lm
	–	2.6×10^{-13}[p]	7.7×10^{-13}[p]	W
Equivalent Noise Input[s]	–	1.8×10^{-12}	–	lm
	–	1.7×10^{-15}[r]	–	W
Pulse Height Resolution[q]	–	7.5	–	%
Mean Gain Deviation:[t]				
With count rate change of 10,000 to 1,000 cps[u]	–	1	–	%
For period of 16 hours at a count rate of 10,000 cps[v]	–	1	–	%
Anode-Pulse Rise Time[w,x] at 2000 V	–	1.3×10^{-8}	–	s
Electron Transit Time[w,y] at 2000 V	–	5.8×10^{-8}	–	s

[a] Made by Cinch Manufacturing Company, 1501 Morse Avenue, Elk Grove Village, IL 60007.

[b] Magnetic shielding material in the form of foil or tape as available from the Magnetic Shield Division, Perfection Mica Company, 1322 North Elston Avenue, Chicago, IL, 60622, or equivalent.

[d] Averaged over any interval of 30 seconds maximum.

[e] Tube operation at room temperature or below is recommended.

[f] This value is calculated from the typical anode luminous sensitivity rating using a conversion factor of 1040 lumens per watt.

[g] These values are calculated as shown below:

$$\text{Luminous Sensitivity (A/lm)} = \frac{\text{Anode Current with blue light source) (A)}}{\text{0.12 x Light Flux of } 1 \times 10^{-5} \text{ (lm)}}$$

The value of 0.12 is the average value of the ratio of the anode current measured under the conditions specified in footnote (h) to the anode current measured with the blue filter removed.

[h] Under the following conditions: 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 10 microlumens.

[j] This value is calculated from the typical cathode luminous sensitivity rating using a conversion factor of 1040 lumens per watt.

[k] This value is calculated as shown below:

$$\text{Cathode Luminous Sensitivity (A/lm)} = \frac{\text{Cathode Current (with blue light source) (A)}}{\text{0.12 x Light Flux of } 1 \times 10^{-4} \text{ (lm)}}$$

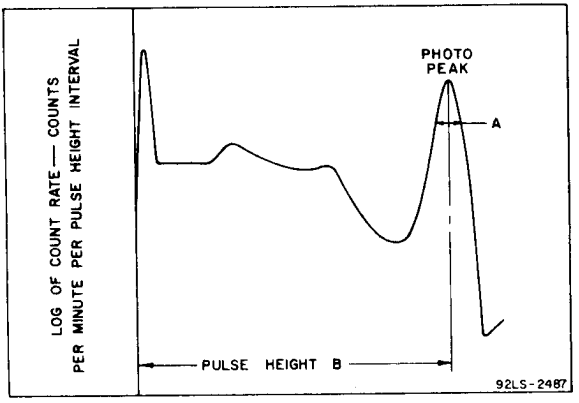
The value of 0.12 is the average value of the ratio of the cathode current measured under the conditions specified in footnote (m) to the cathode current measured under the same conditions but with the blue filter removed.

[m] Under the following conditions: 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 1×10^{-4} lumen and 300 volts are applied between cathode and all other electrodes connected as anode.

n 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 10 microlumens. The supply voltage E is adjusted to obtain an anode current of 9 microamperes. Sensitivity of the 4521 under these conditions is approximately equivalent to 7.5 amperes per lumen. Dark current is measured with no light incident on the tube.

p At 4000 angstroms. These values are calculated from the EADCI values in lumens using a conversion factor of 1040 lumens per watt.

q With a supply voltage E of 1100 volts. Anode load is a 100-kilohm resistor in parallel with a total capacitance of 100 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. The 662 keV photon from an isotope of cesium having an atomic mass of 137 (Cs^{137}) and a cylindrical 3" x 3" thallium-activated sodium-iodide scintillator [NaI (Tl)-type 12A12, Serial No.DH184 or equivalent] are used. This scintillator is manufactured by the Harshaw Chemical Corporation, 1945 East 97th Street, Cleveland 6, OH. The Cs^{137} source is in direct contact with the metal end of the scintillator. The faceplate end of the crystal is coupled to the tube by a coupling fluid such as Dow Corning Corp. Type DC200 (Viscosity of 60,000 centistokes) — Manufactured by the Dow Corning Corp., Midland, MI, or equivalent. Pulse-height resolution in per cent is defined at 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).



r At 4000 angstroms. This value is calculated from the ENI value in lumens using a conversion factor of 1040 lumens per watt.

s Under the following conditions: External shield connected to cathode, an equivalent bandwidth of 1 Hz, tungsten-light source at a color temperature of 2870° K interrupted at a low audio frequency to produce incident radiation pulses alternating between zero and the value stated. The "on" period of the pulse is equal to the "off" period.

t Mean gain deviation is defined as follows:

$$MGD = \frac{\sum_{i=1}^{i=n} |\bar{p} - p_i|}{n} \cdot \frac{100}{\bar{p}}$$

Where:

$\bar{p}$ = mean pulse height

p_i = pulse height at the "i^{th}" reading

n = total number of readings

u Under the following conditions: The scintillator and Cs^{137} radiation source of (s) are employed. The radiation source is initially centered, on the major axis of the tube and the scintillator, at a point providing a pulse count rate of 10,000 cps. The pulse height of the photopeak is measured under this condition. Next, the radiation source is moved rapidly, in approximately 30 seconds, to a new position that is equivalent to a count rate of 1,000 cps. The new position is also centered in the major axis of the tube. The pulse height under this condition is measured. Mean gain deviation is defined as shown in (t).

v Under the same conditions as shown in (u) except the tube is operated for a period of 1/2 hour with the radiation source located at the point providing a pulse count rate of 10,000 cps. Following this time interval, the pulse height is sampled, at this count rate, at 1-hour intervals for a period of 16 hours. Mean gain deviation is defined as shown in (t).

w Under conditions with dc supply voltage (E) across a voltage divider providing 1/6 of E between cathode and dynode No.1; 1/12 of E for each succeeding dynode stage; and 1/12 of E between dynode No.10 and anode.

x 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.

y The electron transit time is the time 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.

OPERATING CONSIDERATIONS

Terminal Connections

The 4521 is supplied with a small-shell diheptal base attached to semiflexible leads to facilitate testing. After testing, the attached base should be removed prior to installing the 4521 in a given system.

SHIELDING

Electrostatic and magnetic shielding of the 4521 is usually required. When a shield is used it must be at cathode potential.

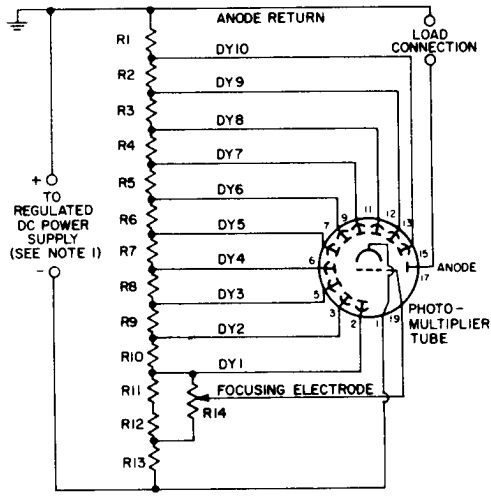
OPERATING VOLTAGES

The high voltages at which the 4521 is operated are very dangerous. Care should be taken in the design of apparatus to prevent the operator from coming in contact with these high voltages.

For additional information on this type write to RCA Commercial Engineering, Harrison, N.J. 07029 for technical bulletin.

Voltage To Be Provided By Divider	
Between	**7.7% of Supply Voltage (E) Multiplied by**
Cathode and Dynode No.1	3
Dynode No.1 and Dynode No.2	1
Dynode No.2 and Dynode No.3	1
Dynode No.3 and Dynode No.4	1
Dynode No.4 and Dynode No.5	1
Dynode No.5 and Dynode No.6	1
Dynode No.6 and Dynode No.7	1
Dynode No.7 and Dynode No.8	1
Dynode No.8 and Dynode No.9	1
Dynode No.9 and Dynode No.10	1
Dynode No.10 and Anode	1
Anode and Cathode	13
The focus voltage shall be adjusted to the potential which gives maximum anode current and is between 70 and 100 per cent of dynode No.1 potential (referred to cathode).	

TYPICAL VOLTAGE-DIVIDER ARRANGEMENT FOR GENERAL PHOTOMETRIC APPLICATIONS



R_1 through R_{13}: 470 kΩ, 5%, 1/2 W

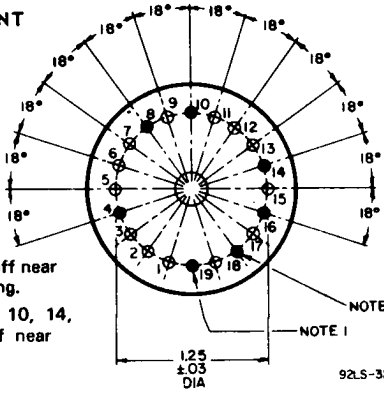
R_{14}: 5 MΩ, 20%, 1/2 W, (Adjustable)

Note 1: Adjustable between approximately 800 and 2000 volts dc.

Note 2: Component values are dependent upon nature of application and output signal desired.

BASE ARRANGEMENT

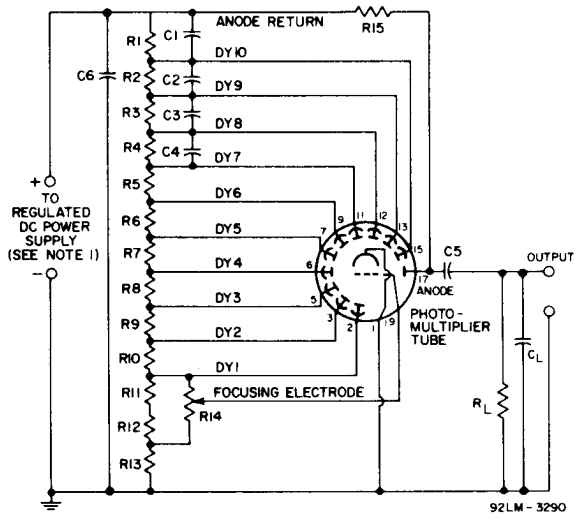
BOTTOM VIEW



Note 1: Lead is cut off near glass button for indexing.

Note 2: Leads 4, 8, 10, 14, 16, and 18 are cutoff near button.

TYPICAL VOLTAGE-DIVIDER ARRANGEMENT FOR SCINTILLATION-COUNTING APPLICATIONS



C_1: 0.05 μF, 500 volts
C_2: 0.02 μF, 500 volts
C_3: 0.01 μF, 500 volts
C_4: 0.005 μF, 500 volts
C_5 and C_6: 0.005 μF, 3000 volts
R_1 through R_{13}: 470 kΩ, 5%, 1/2 W
R_{14}: 5 MΩ, 20%, 1/2 W, (Adjustable)
R_{15}: 1 MΩ, 5%, 1/2 W
R_L: 100 kΩ, 5%, 1/2 W

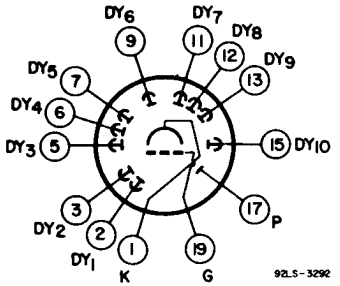
Note 1: Adjustable between approximately 800 and 2000 volts dc.

Note 2: Capacitors C_1 through C_6 should be connected at tube socket for optimum high-frequency performance.

Note 3: The value of the load elements, R_L and C_L, depend on the application. For most applications, $R_L \times C_L = 10$ microseconds. It is to be noted that R_{15} is in parallel with R_L and must be considered when selecting the R_L value.

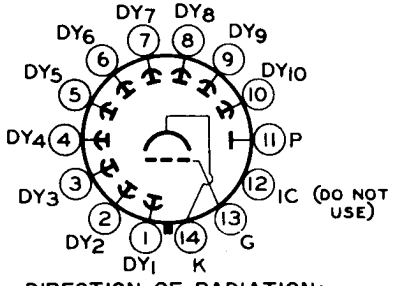
Note 4: Component values are dependent upon nature of application and output signal desired.

LEAD CONNECTIONS
BOTTOM VIEW (WITH BASE REMOVED)



Lead 1: Photocathode
Lead 2: Dynode No.1
Lead 3: Dynode No.2
Lead 5: Dynode No.3
Lead 6: Dynode No.4
Lead 7: Dynode No.5
Lead 9: Dynode No.6
Lead 11: Dynode No.7
Lead 12: Dynode No.8
Lead 13: Dynode No.9
Lead 15: Dynode No.10
Lead 17: Anode
Lead 19: Focusing Electrode

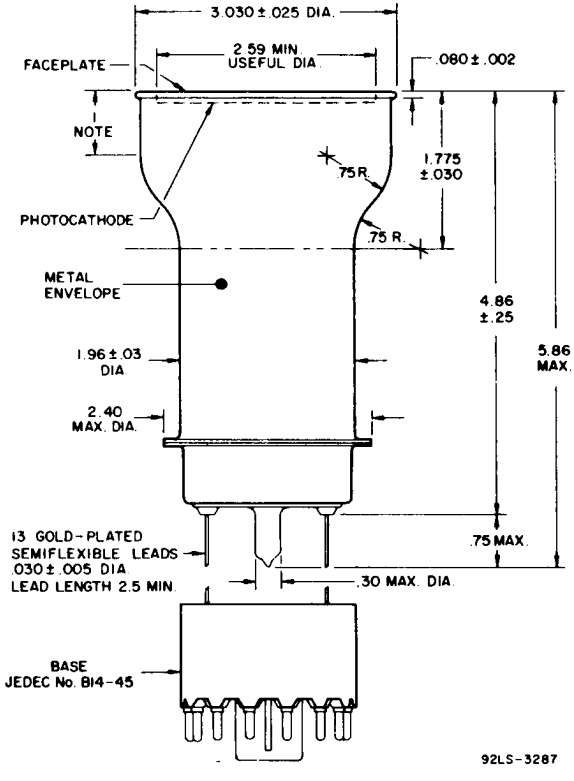
BASING DIAGRAM
BOTTOM VIEW (WITH TEMPORARY BASE)



DIRECTION OF RADIATION: INTO END OF BULB

Pin 1: Dynode No.1
Pin 2: Dynode No.2
Pin 3: Dynode No.3
Pin 4: Dynode No.4
Pin 5: Dynode No.5
Pin 6: Dynode No.6
Pin 7: Dynode No.7
Pin 8: Dynode No.8
Pin 9: Dynode No.9
Pin 10: Dynode No.10
Pin 11: Anode
Pin 12: Internal Connection—Do Not Use
Pin 13: Focusing Electrode
Pin 14: Photocathode

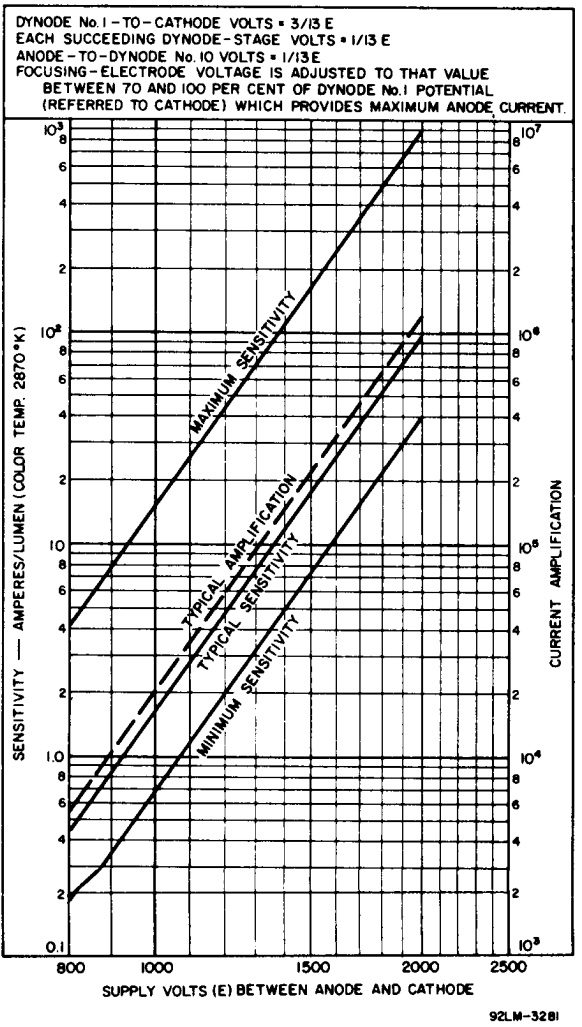
DIMENSIONAL OUTLINE



Dimensions are in inches unless otherwise stated.

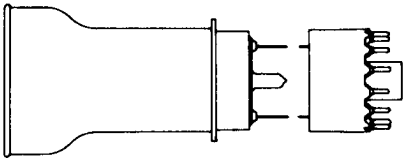
Inch	mm	Inch	mm
.005	.127	2.34	59.4
.025	.63	2.40	60.9
.030	.76	2.5	63.5
.08	2.0	2.59	66
.25	6.3	3.03	76.9
.75	19.1	4.86	123.4
2.0	50.8	5.86	148.8

SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS

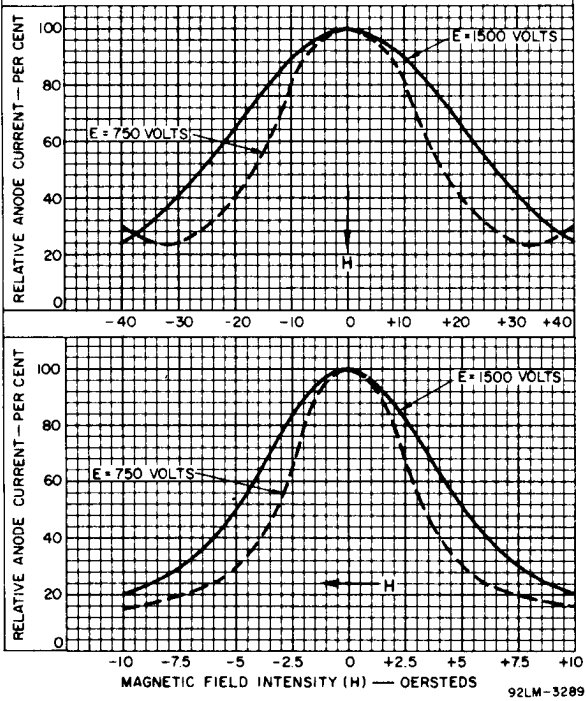


TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT

SUPPLY VOLTAGE (E) ACROSS VOLTAGE DIVIDER PROVIDING 3/13 OF E BETWEEN CATHODE AND DYNODE No.1, 1/13 OF E FOR EACH SUCCEEDING DYNODE STAGE, AND 1/13 OF E BETWEEN DYNODE No.10 AND ANODE.
FOCUSING ELECTRODE ADJUSTED TO GIVE MAXIMUM ANODE CURRENT.
PHOTOCATHODE IS FULLY ILLUMINATED.
TUBE IS ORIENTED IN MAGNETIC FIELD AS SHOWN BELOW:

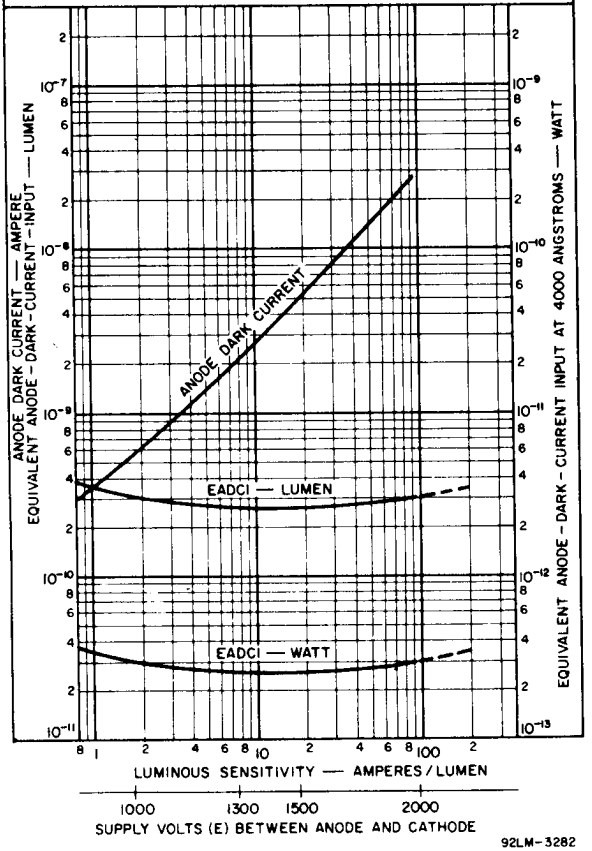


POSITIVE VALUES OF MAGNETIC FIELD INTENSITY (H) ARE FOR LINES OF FLUX IN INDICATED DIRECTION.

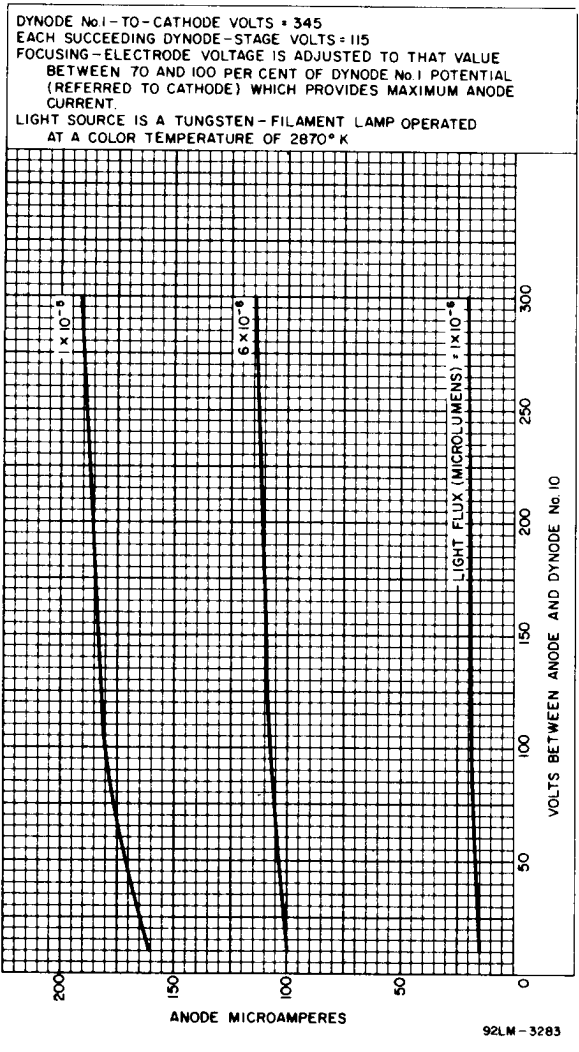


TYPICAL EADCI AND ANODE DARK CURRENT CHARACTERISTICS

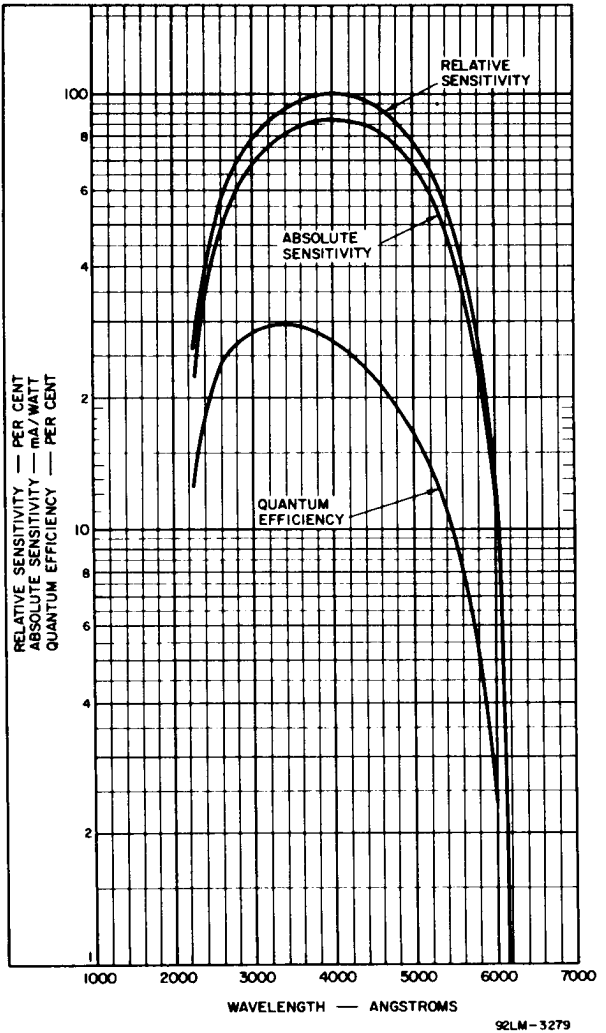
LUMINOUS SENSITIVITY IS VARIED BY ADJUSTMENT OF THE SUPPLY VOLTAGE (E).
DYNODE No.1 - TO - CATHODE VOLTS = 3/13 E
EACH SUCCEEDING DYNODE - STAGE VOLTS = 1/13 E
FOCUSING - ELECTRODE VOLTAGE IS ADJUSTED TO THAT VALUE BETWEEN 70 AND 100 PER CENT OF DYNODE No.1 POTENTIAL (REFERRED TO CATHODE) WHICH PROVIDES MAXIMUM ANODE CURRENT.
LIGHT SOURCE IS A TUNGSTEN - FILAMENT LAMP OPERATED AT A COLOR TEMPERATURE OF 2870°K.



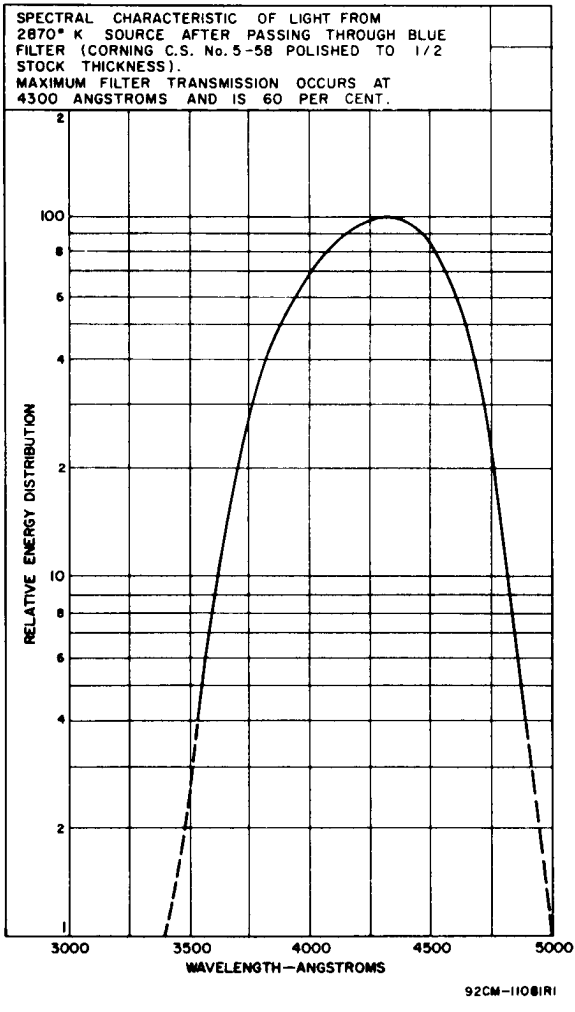
TYPICAL ANODE CHARACTERISTICS



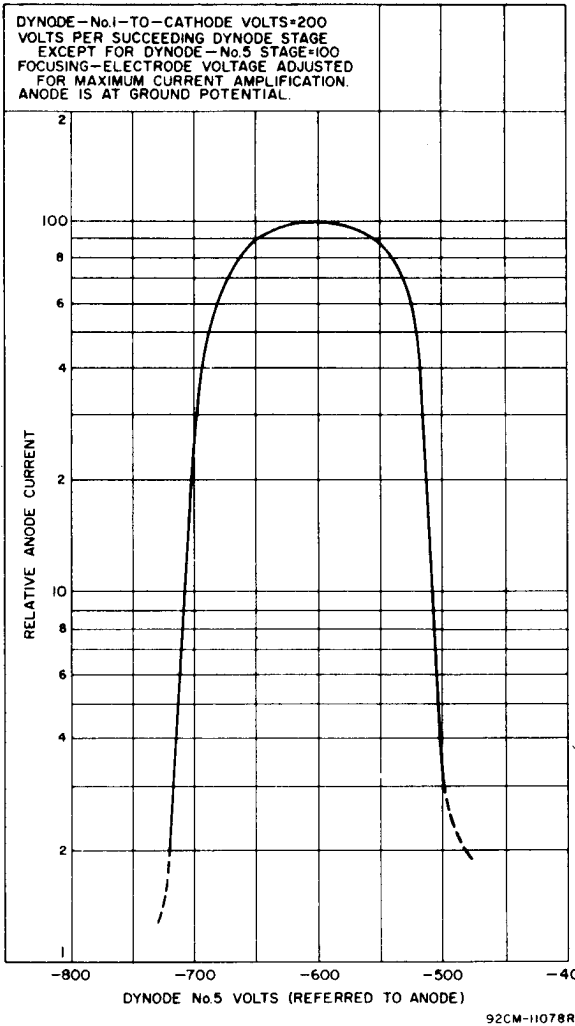
TYPICAL SPECTRAL RESPONSE CHARACTERISTICS



SPECTRAL ENERGY DISTRIBUTION OF 2870° K LIGHT SOURCE AFTER PASSING THROUGH INDICATED FILTER

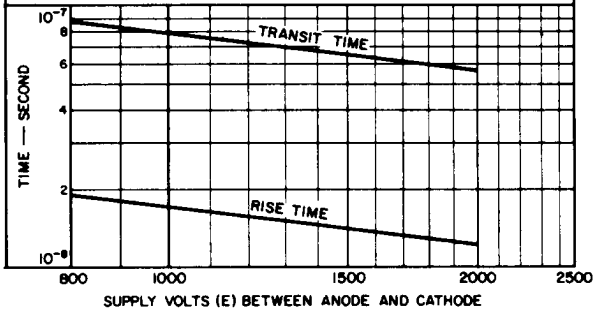


TYPICAL CHARACTERISTIC OF OUTPUT CURRENT AS A FUNCTION OF DYNODE-NO. 5 VOLTS



TYPICAL TIME RESOLUTION CHARACTERISTICS

DYNODE No.1-TO-CATHODE VOLTS = 1/6 E
EACH SUCCEEDING DYNODE-STAGE VOLTS = 1/12 E
ANODE-TO-DYNODE No. 10 VOLTS = 1/12 E
FOCUSING-ELECTRODE VOLTAGE IS ADJUSTED TO THAT VALUE BETWEEN 70 AND 100 PER CENT OF DYNODE No.1 POTENTIAL (REFERRED TO CATHODE) WHICH PROVIDES MAXIMUM ANODE CURRENT.
PHOTOCATHODE IS FULLY ILLUMINATED.



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