

# Photomultiplier Tube

2"-Diameter, 12-Stage, Head-On Type Having  
Bialkali Photocathode and In-Line Electrostatically-  
Focused Dynode Structure

## GENERAL

Spectral Response	See accompanying <i>Typical Photocathode Spectral Response Characteristics</i>
Wavelength of Maximum Response	3850 ± 500 angstroms
Cathode, Semitransparent	Cesium-Potassium-Antimony (Bialkali)
Minimum projected area	2.54 sq. in
Minimum diameter	1.80 in
Window	Pyrex, Corning® No.7740, or equivalent
Shape	Plano-Concave
Index of refraction at 5893 angstroms	1.47
Dynodes:	
Substrate	Copper-Beryllium
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
Maximum Overall Length	5.71 in
Seated Length	4.98 ± 0.08 in
Maximum Diameter	2.10 in
Bulb	T16
Base	See Base Drawing
Socket	RCA AJ2144 or AJ2145 <sup>b</sup>
Magnetic Shield	See footnote (c)
Operating Position	Any
Weight (Approx.)	6 oz

## MAXIMUM AND MINIMUM RATINGS, *Absolute-Maximum Values:*

DC Supply Voltage:

Between anode and cathode:

With Voltage Distribution A shown in Table I	}	3000 max.	V
		800 min.	V
With Voltage Distribution B shown in Table I	}	3000 max.	V
		1300 min.	V

With Voltage Distribution C shown in Table I . . . . .	}	3500 max.	V
		800 min.	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 . . . . .	}	1000 max.	V
		300 min.	V
Between focusing electrode and cathode . . . . .		1000 max.	V
Average Anode Current <sup>e</sup> . . . . .		0.2 max.	mA
Ambient-Temperature Range <sup>f</sup> . . . . .		-100 to +85	°C

### CHARACTERISTICS RANGE VALUES

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

With E = 2000 volts (Except as noted)

#### Voltage Distribution A, Table I

	Min.	Typical	Max.	
<b>Anode Sensitivity:</b>				
Radiant <sup>g</sup> at 3850 angstroms . . . . .	—	9.7x10 <sup>5</sup>	—	A/W
Luminous <sup>h</sup> (2870° K) . . . . .	100	850	3000	A/lm
Current with blue light source <sup>i</sup> (2870° K + C.S. No.5-58) . . . . .	1.3x10 <sup>-6</sup>	1.1x10 <sup>-5</sup>	4x10 <sup>-5</sup>	A
<b>Cathode Sensitivity:</b>				
Radiant <sup>k</sup> at 3850 angstroms . . . . .	—	0.097	—	A/W
Luminous <sup>m</sup> (2870° K) . . . . .	6.2x10 <sup>-5</sup>	8.5x10 <sup>-5</sup>	—	A/lm
Current with blue light source <sup>n</sup> (2870° K + C.S. No.5-58) . . . . .	8x10 <sup>-10</sup>	1.1x10 <sup>-9</sup>	—	A
Quantum Effi- ciency at 3850 angstroms <sup>p</sup> . . . . .	—	31	—	%
Current Amplifica- tion . . . . .	—	1x10 <sup>7</sup>	—	
Anode Dark Current <sup>q</sup> . . . . .	—	1x10 <sup>-9</sup>	4x10 <sup>-9</sup>	A

—> Indicates a change or addition.

Equivalent Anode Dark Current In- put <sup>q</sup> . . . . .	}	—	$5 \times 10^{-12}$	$2 \times 10^{-11}$	Im
		—	$4.4 \times 10^{-15r}$	$1.8 \times 10^{-14r}$	W
Equivalent Noise Input <sup>s</sup> . . . . .	}	—	$1.8 \times 10^{-13}$	—	Im
		—	$1.6 \times 10^{-16t}$	—	W
<b>Dark Pulse Sum- mation<sup>u</sup>:</b>					
1/8 photoelectron to 16 photoelectrons . . . . .	—	660	—	counts per seconds	
<i>See Typical Dark-Pulse Spectrum</i>					
Anode-Pulse Rise Time <sup>v</sup> at 3000 V . . . . .	—	$2.1 \times 10^{-9}$	—	s	
Electron Transit Time <sup>w</sup> at 3000 V . . . . .	—	$3.1 \times 10^{-8}$	—	s	
<b>With E = 1100 volts (Except as noted)</b>					
<b>Voltage Distribution A, Table I</b>					
Pulse Height Resolution <sup>x</sup> . . . . .	—	7.5	8	%	
Pulse Height <sup>y</sup> . . . . .	$4.9 \times 10^{-12}$	$1.5 \times 10^{-11}$	$1.5 \times 10^{-10}$	coulombs	
Peak-to-Valley Ratio of Pulse Height Spectrum with Fe <sup>55</sup> Source <sup>z</sup> . . . . .	—	38	—		
<b>Mean Gain De- viation:<sup>aa</sup></b>					
With count rate change of 1000 to 10000 cps <sup>bb</sup> . . . . .	—	1	—	%	
For a period of 16 hours at a count rate of 1000 cps <sup>cc</sup> . . . . .	—	1	—	%	
<b>With E = 3000 volts</b>					
<b>Voltage Distribution C, Table I</b>					
<b>Pulse Current:<sup>dd</sup></b>					
Linear <sup>ee</sup> . . . . .	—	0.15	—	A	
Space-charge limited (saturated)	—	0.50	—	A	

- a Made by Corning Glass, Corning, NY 14830.
- b The AJ2145 is ordinarily supplied with the tube and is designed specifically for chassis mounting. The AJ2144 may be supplied as an alternate socket if requested by the user. The AJ2144 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.
- c 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.
- e Averaged over any interval of 30 seconds maximum.
- f Tube operation at room temperature or below is recommended.
- g This value is calculated from the typical anode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.
- h These values are calculated as shown below:

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

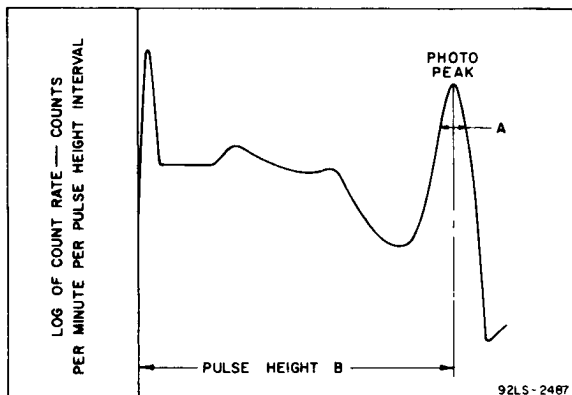
The value of 0.13 is the average value of the ratio of the anode current measured under the conditions specified in footnote (j) to the anode current measured under the same conditions but with the blue filter removed.

- j 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—Manufactured by the Corning Glass Works, Corning, NY 14830) from a tungsten-filament lamp operated at a color temperature of 2870° K. The value of light flux incident on the filter is  $1 \times 10^{-7}$  lumen.
- k This value is calculated from the typical cathode luminous sensitivity rating using a conversion factor of 1140 lumens per watt.
- m These values are calculated as shown below:

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

- The value of 0.13 is an average value. It is the ratio of the cathode current measured under the conditions specified in footnote (n) to the cathode current measured under the same conditions but with the blue filter removed.
- n 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 500 volts are applied between cathode and all other electrodes connected as anode.
  - P Calculated from the cathode current measured with blue light source.
  - q 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 2.6 microamperes. Luminous sensitivity of the tube under these conditions is approximately equivalent to 200 amperes per lumen. Dark current is measured with incident light removed.
  - r At 3850 angstroms. These values are calculated from the EADCI values in lumens using a conversion factor of 1140 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 At 3850 angstroms. This value is calculated from the ENI value in lumens using a conversion factor of 1140 lumens per watt.
  - u Measured as shown under (q) and with the tube in complete 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 the dark pulse summation is measured.
  - v 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.

- w 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.
- x Anode load is a 100 kilohm resistor with a total capacitance of  $100 \pm 3\%$  pF in parallel. 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 a 1 microcurie  $\text{Cs}^{137}$  source and a cylindrical 2" x 2" thallium-activated sodium-iodide scintillator [NaI (TI)-type 8D8S50, Serial No. BR772, or equivalent] are used. This scintillator is manufactured by the Harshaw Chemical Corporation, 1945 East 97th Street, Cleveland 6, OH, and is rated by the manufacturer as having a resolving capability of 8.2 per cent to 8.3 per cent. The  $\text{Cs}^{137}$  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 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).



- Y** Pulse height is defined as the average charge collected at the anode from a pulse caused by the photoelectric absorption of a 662 keV photon from  $\text{Cs}^{137}$  in a thallium-activated sodium-iodide scintillator,  $\text{NaI(Tl)}$ .
- Z** Measured using a Harshaw Type HG 0.005" beryllium window  $\text{NaI(Tl)}$  scintillator, 0.04" thick and 7/8" in diameter and an isotope of iron having an atomic mass of 55 ( $\text{Fe}^{55}$ ) and an effective activity at the scintillator of one microcurie.
- aa** Mean gain deviation is defined as follows:

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

where:  $\bar{p}$  = mean pulse height

$p_i$  = pulse height at the "i"th reading

$n$  = total number of readings

- bb** Under the following conditions: The scintillator and  $\text{Cs}^{137}$  radiation source of (x) 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 1000 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 10,000 cps. The new position is also centered in the major axis of the tube. The pulse height under this condition is measured. The difference in pulse height between these two measurements is typically 1 per cent.
- cc** Under the same conditions as (bb) except the count rate position of 1,000 cps is maintained for 16 hours and the pulse height is sampled at 1 hour intervals.
- dd** The interstage voltages of the tube should not deviate more than 2 per cent from the specified voltage distribution. Capacitors are connected across the individual resistors making up the voltage-divider arrangement to insure this operating condition.
- ee** Maximum deviation from linearity is 2 per cent.

Table I

## Voltages To Be Provided By Divider

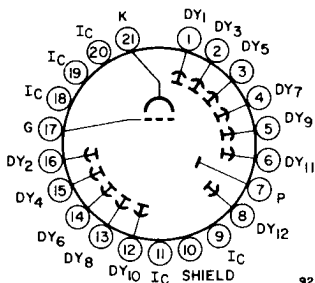
Between the Following Electrodes: Cathode (K), Dynode (Dy), and Anode (P)	Column A	Column B	Column C
	6.1% of Supply Voltage (E) multiplied by	8.06% of Dy1 - P Voltage (E) multiplied by	4.6% of Supply Voltage (E) multiplied by
K - Dy1	4.0	⚡	4.0
Dy1 - Dy2	1.0	1.0	1.0
Dy2 - Dy3	1.4	1.4	1.4
Dy3 - Dy4	1.0	1.0	1.0
Dy4 - Dy5	1.0	1.0	1.0
Dy5 - Dy6	1.0	1.0	1.0
Dy6 - Dy7	1.0	1.0	1.0
Dy7 - Dy8	1.0	1.0	1.0
Dy8 - Dy9	1.0	1.0	1.0
Dy9 - Dy10	1.0	1.0	1.5
Dy10 - Dy11	1.0	1.0	2.0
Dy11 - Dy12	1.0	1.0	4.0
Dy12 - P	1.0	1.0	2.0
Dy1 - P	—	12.4	—
K - P	16.4	—	21.9

Focusing Electrode (Pin 17) connected to dynode No.1 potential.  
Electron Multiplier Shield (Pin 10) connected to dynode No.5 potential.

⚡ Cathode-to-Dynode-No.1 Voltage maintained at 660 volts.

## TERMINAL CONNECTIONS

The base pins of the tube fit a 21-contact socket such as the RCA-AJ2144 and the AJ2145.

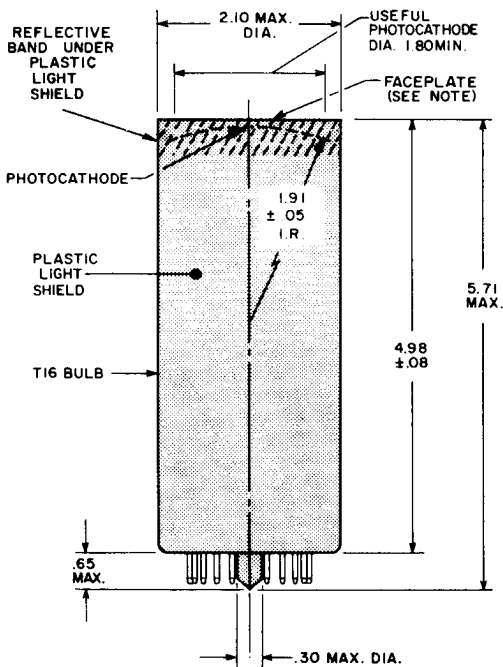
BASING DIAGRAM  
(BOTTOM VIEW)

DIRECTION OF RADIATION:  
INTO END OF BULB

92LS-2812



## DIMENSIONAL OUTLINE



92CS-13038R2

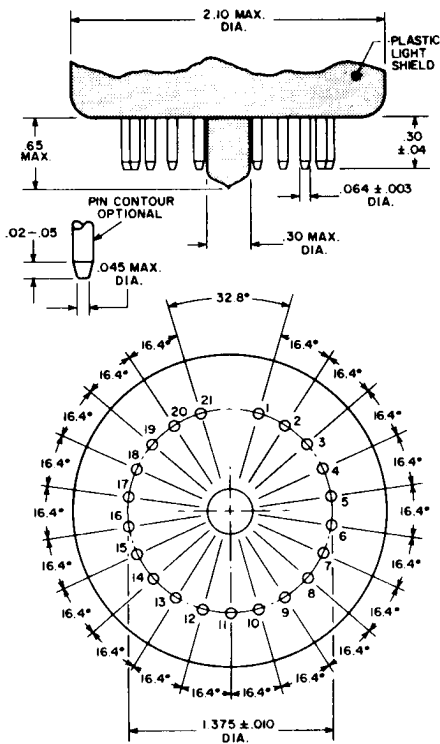
Dimensions in Inches

**Note:** Deviation from Flatness of External Surface of Faceplate will not exceed 0.010" from Peak to Valley.

The dimensions in millimeters are derived from the basic inch dimensions (1 inch = 25.4 mm).

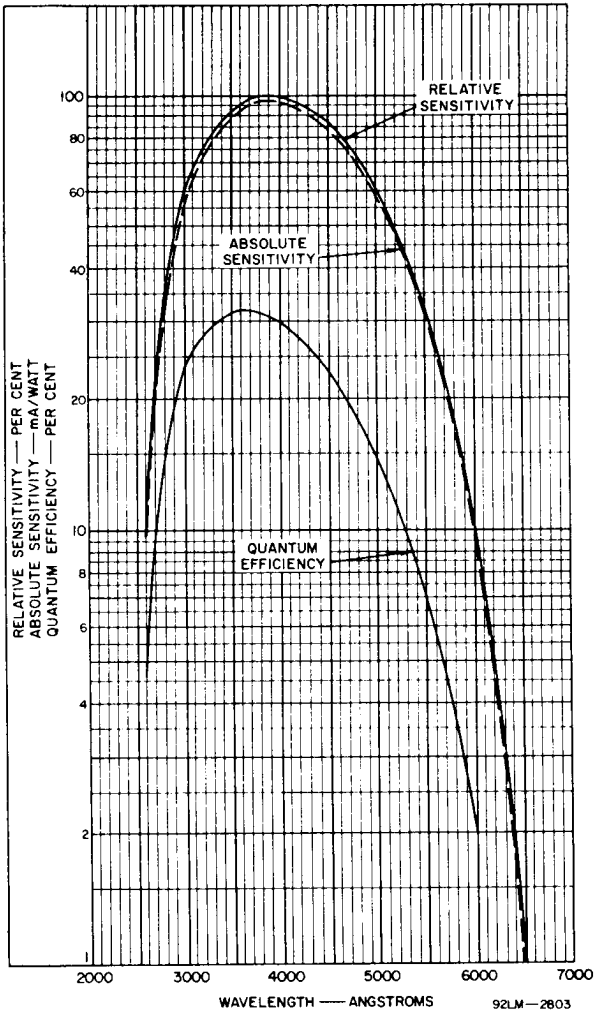
Inch	mm	Inch	mm	Inch	mm
.003	.08	.05	1.3	1.375	34.93
.010	.25	.064	1.63	1.80	45.7
.02	.5	.08	2.0	1.91	48.5
.04	1.0	.30	7.6	2.10	53.3
.045	1.14	.65	16.5	4.98	126.5
				5.71	145.0

## DETAIL OF BASE ARRANGEMENT



92CS-13040R2

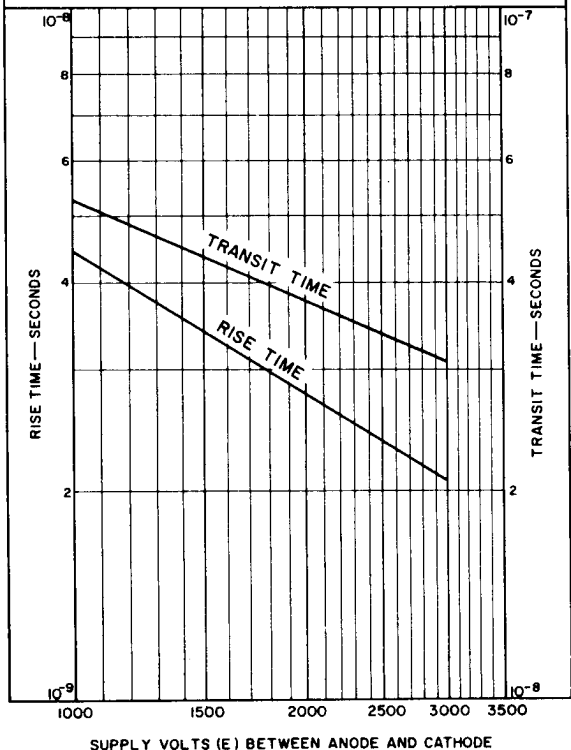
- |  |  |
|--|--|
| Pin 1: Dynode No.1                         | Pin 12: Dynode No.10                       |
| Pin 2: Dynode No.3                         | Pin 13: Dynode No.8                        |
| Pin 3: Dynode No.5                         | Pin 14: Dynode No.6                        |
| Pin 4: Dynode No.7                         | Pin 15: Dynode No.4                        |
| Pin 5: Dynode No.9                         | Pin 16: Dynode No.2                        |
| Pin 6: Dynode No.11                        | Pin 17: Focusing Electrode                 |
| Pin 7: Anode                               | Pin 18: Internal Connection,<br>Do not use |
| Pin 8: Dynode No.12                        | Pin 19: Internal Connection,<br>Do not use |
| Pin 9: Internal Connection,<br>Do not use  | Pin 20: Internal Connection,<br>Do not use |
| Pin 10: Electron Multiplier Shield         | Pin 21: Photocathode                       |
| Pin 11: Internal Connection,<br>Do not use |  |

TYPICAL PHOTOCATHODE SPECTRAL RESPONSE  
CHARACTERISTICS

## TYPICAL TIME-RESOLUTION CHARACTERISTICS

THE SUPPLY VOLTAGE (E) IS ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS:	
BETWEEN	6.1% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	4.0
DYNODE No. 1 AND DYNODE No. 2	1.0
DYNODE No. 2 AND DYNODE No. 3	1.4
EACH SUCCEEDING DYNODE-STAGE VOLTS	1.0
ANODE AND CATHODE	16.4

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



92CM-13042

## TYPICAL ANODE DARK CURRENT AND EADCI CHARACTERISTICS

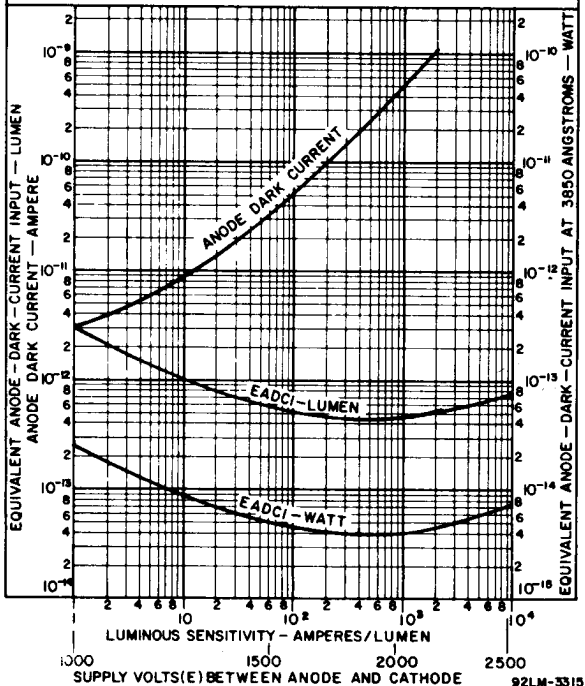
LUMINOUS SENSITIVITY IS VARIED BY ADJUSTMENT OF THE SUPPLY VOLTAGE (E) ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS:

BETWEEN	6.1% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	4.0
DYNODE No. 1 AND DYNODE No. 2	1.0
DYNODE No. 2 AND DYNODE No. 3	1.4
EACH SUCCEEDING DYNODE-STAGE VOLTS	1.0
ANODE AND CATHODE	16.4

ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE No. 5 POTENTIAL.

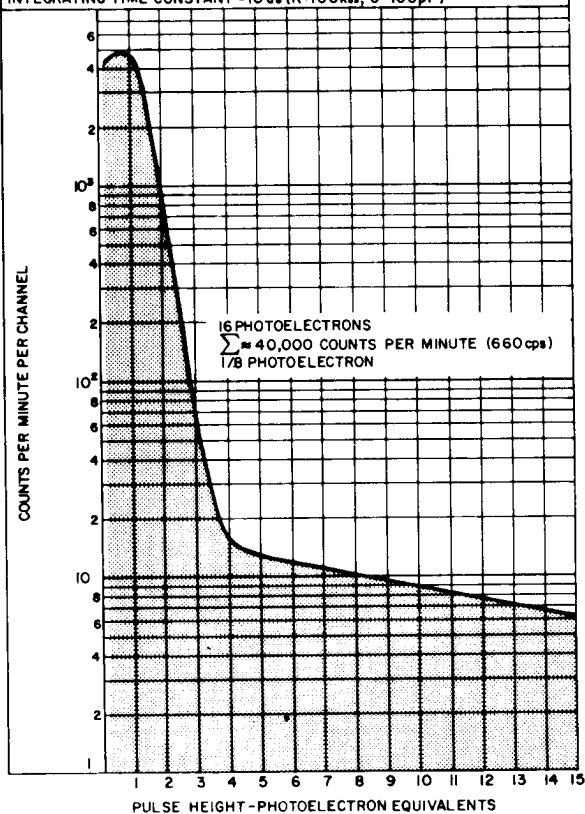
FOCUSING ELECTRODE IS CONNECTED TO DYNODE No. 1 POTENTIAL.  
LIGHT SOURCE IS A TUNGSTEN-FILAMENT LAMP OPERATED AT A COLOR TEMPERATURE OF 2870°K.

TUBE TEMPERATURE = 22°C



## TYPICAL DARK-PULSE SPECTRUM

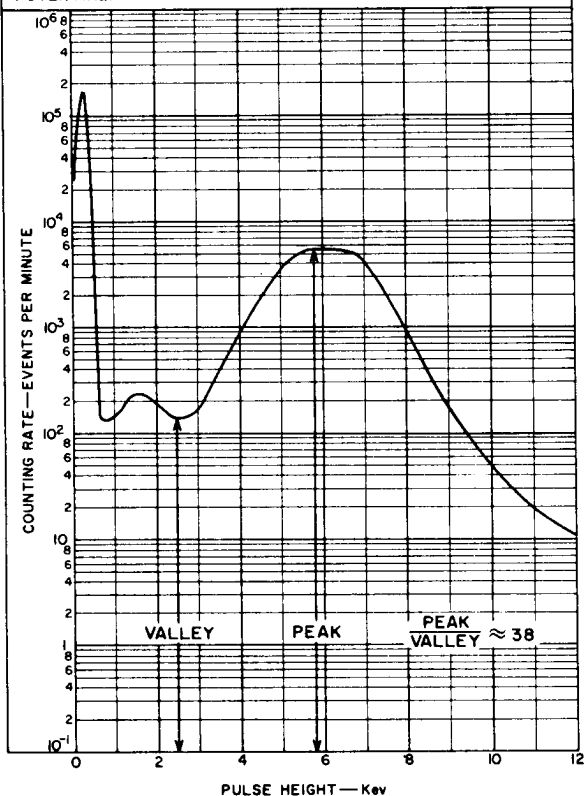
MEASURED UNDER THE FOLLOWING CONDITIONS: LIGHT ON CATHODE IS TRANSMITTED THROUGH A BLUE FILTER (CORNING CS No. 5-58, POLISHED TO 1/2 STOCK THICKNESS). LIGHT ON FILTER IS 0.1 MICROLUMEN. VOLTAGE DISTRIBUTION(A) IS USED AND SUPPLY VOLTAGE ADJUSTED TO OBTAIN AN ANODE CURRENT OF 2.6 MICRO-AMPERES. LIGHT IS EXCLUDED DURING MEASUREMENT. FOCUSING ELECTRODE IS CONNECTED TO DYNODE-NO 1 POTENTIAL. ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-NO 5 POTENTIAL. TUBE TEMPERATURE = 22°C. ONE PHOTOELECTRON PULSE HEIGHT = 8 COUNTING CHANNELS. INTEGRATING TIME CONSTANT = 10  $\mu$ s (R=100k $\Omega$ , C=100pF).



92LM-3314

DIFFERENTIAL  $Fe^{55}$  SPECTRUM

$Fe^{55}$  SOURCE, ACTIVITY  $1 \mu$  CURIE  
 SCINTILLATOR: HARSHAW, TYPE HG 0.005" BERYLLIUM WINDOW,  
 $NaI(Tl)$ , 7/8" DIAMETER, 0.040" THICK  
 CATHODE-TO-DYNODE-No. 1 VOLTS = 420  
 DYNODE-No. 1-TO-DYNODE-No. 2 VOLTS = 105  
 DYNODE-No. 2-TO-DYNODE-No. 3 VOLTS = 155  
 EACH SUCCEEDING DYNODE-STAGE VOLTS = 105  
 ANODE-TO-CATHODE VOLTS = 1700  
 FOCUSING ELECTRODE IS CONNECTED TO DYNODE-No. 1 POTENTIAL.  
 ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-No. 5  
 POTENTIAL.



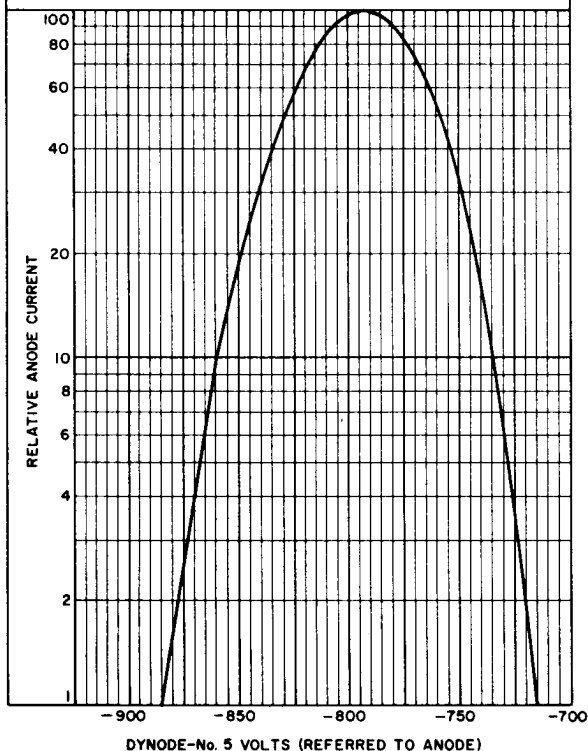
92CM-13047

## TYPICAL DYNODE MODULATION CHARACTERISTIC

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

BETWEEN	6.1% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	4.0
DYNODE No. 1 AND DYNODE No. 2	1.0
DYNODE No. 2 AND DYNODE No. 3	1.4
EACH SUCCEEDING DYNODE-STAGE VOLTS	1.0
ANODE AND CATHODE	16.4

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

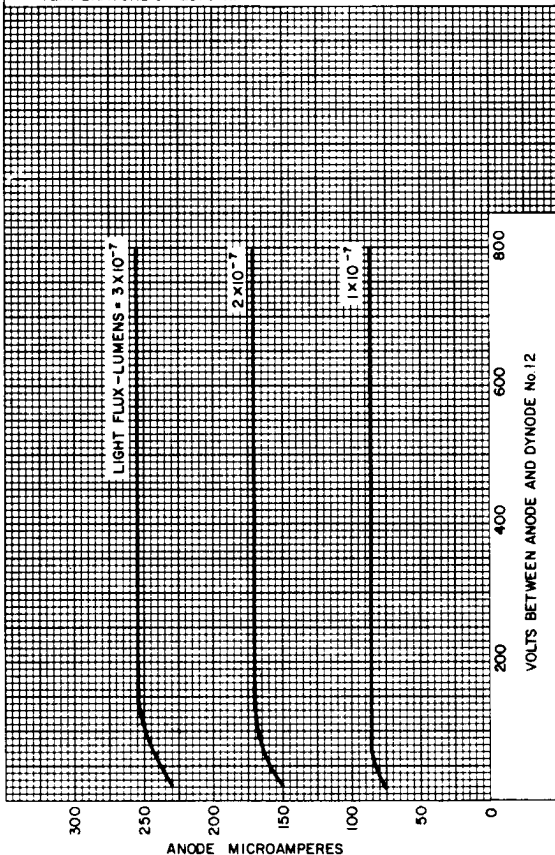


92CM-13044



## TYPICAL ANODE CHARACTERISTICS

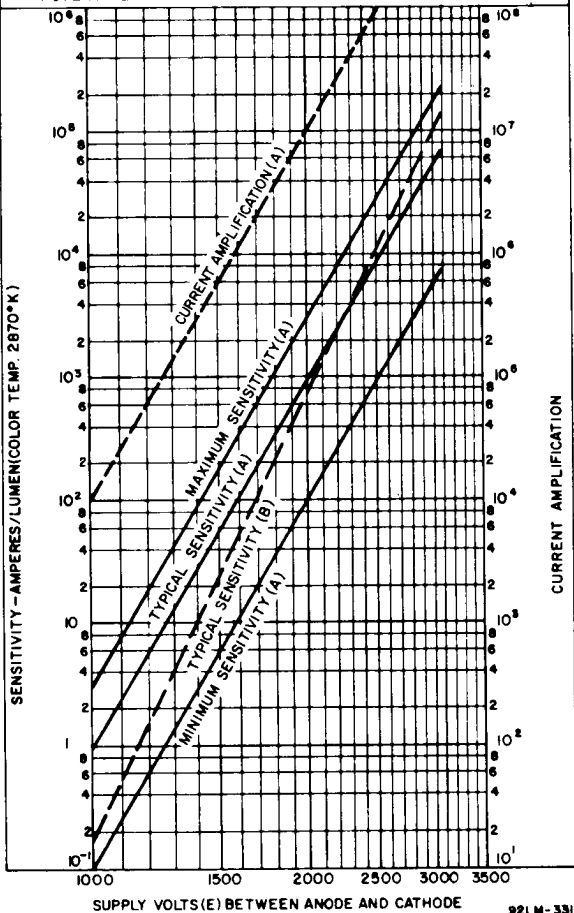
CATHODE-TO-DYNODE-NO.1 VOLTS = 488  
 DYNODE-NO.1-TO-DYNODE-NO.2 VOLTS = 122  
 DYNODE-NO.2-TO-DYNODE-NO.3 VOLTS = 175  
 EACH SUCCEEDING DYNODE-STAGE VOLTS = 122  
 ANODE-TO-CATHODE VOLTS = 2000  
 FOCUSING ELECTRODE IS CONNECTED TO DYNODE-NO.1 POTENTIAL.  
 ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-NO.5 POTENTIAL.  
 LIGHT SOURCE IS A TUNGSTEN-FILAMENT LAMP OPERATED AT A COLOR  
 TEMPERATURE OF 2870°K.



92LM-3313

## TYPICAL SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS

VOLTAGE DISTRIBUTION (A) OR (B) AS SHOWN ON CURVE, TABLE 1.  
 FOCUSING ELECTRODE IS CONNECTED TO DYNODE - No. 1 POTENTIAL.  
 ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE - No. 5  
 POTENTIAL.

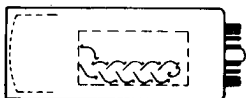


92LM-3312

## TYPICAL EFFECT OF MAGNETIC FIELD ON ANODE CURRENT

THE SUPPLY VOLTAGE (E) IS ACROSS A VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS FOLLOWS.	
BETWEEN:	61% OF E MULTIPLIED BY
CATHODE AND DYNODE No.1	4.0
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	16.4

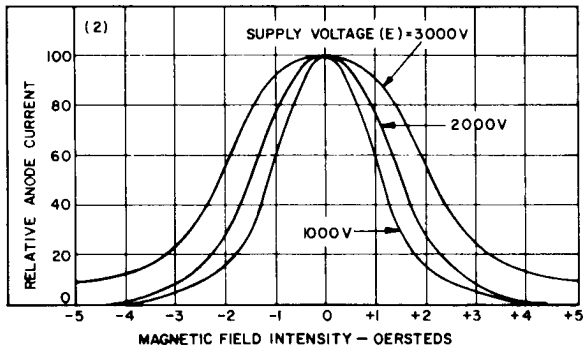
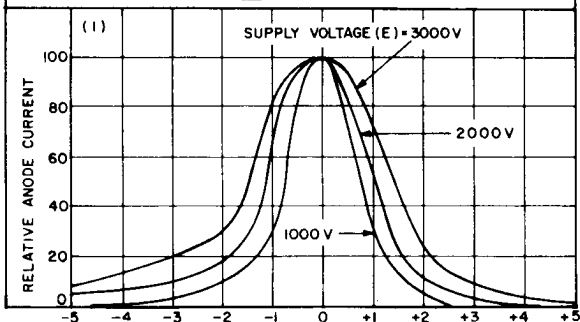
FOCUSING ELECTRODE IS CONNECTED TO DYNODE-NO.1 POTENTIAL.  
ELECTRON MULTIPLIER SHIELD IS CONNECTED TO DYNODE-NO.5 POTENTIAL.  
PHOTOCATHODE IS FULLY ILLUMINATED.



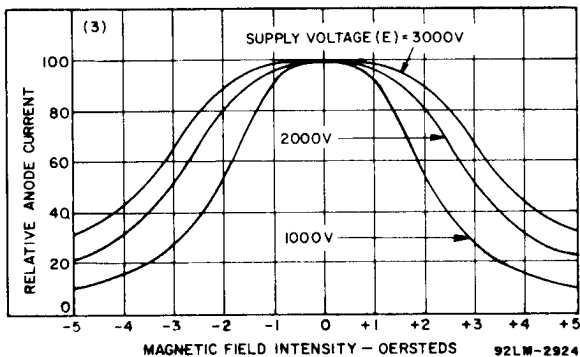
POSITIVE VALUE OF H IN DIRECTION SHOWN:

(1)  $\bullet$ , (2)  $\uparrow$  OR (3)  $\rightarrow$

\* DIRECTION (1) IS OUT OF PAPER



### TYPICAL EFFECT OF MAGNETIC FIELD ON ANODE CURRENT (Cont'd)



### TYPICAL FOCUSING-ELECTRODE CHARACTERISTIC

