Photomultiplier Tubes

10-Stage, Head-On Types Having Bialkali Photocathode.

GENERAL

Spectral Response . . . . . See accompanying *Typical Spectral Response Characteristics*

Wavelength of Maximum Response . . . . . 4000 ± 500 Å

Cathode, Semitransparent . . Potassium-Cesium-Antimony (Bialkali)

Type 4516

Minimum projected area . . . . . 0.2 in^2 (1.26 cm^2)

Minimum diameter . . . . . 0.5 in (1.27 cm)

Type 4517

Minimum projected area . . . . . 1.2 in^2 (7.8 cm^2)

Minimum diameter . . . . . 1.24 in (31.5 mm)

Window . . . . . Corning[a] No.0080, or equivalent

Index of refraction at 4360 angstroms 1.523

Type 4516

Shape . . . . . Plano-Concave

Type 4517

Shape . . . . . Plano-Plano

Dynodes:

Substrate . . . . . Copper-Beryllium

Secondary-Emitting Surface . . . . . Beryllium-Oxide

Structure . . . . . **(4516)** In-Line, Electrostatic-Focus Type
(4517) Circular-Cage, Electrostatic-Focus Type

Direct Interelectrode Capacitances (Approx.):

Type 4516

Anode to dynode No.10 . . . . . 2.4 pF

Anode to all other electrodes . . . . . 3.2 pF

Type 4517

Anode to dynode No.10 . . . . . 4 pF

Anode to all other electrodes . . . . . 7 pF

Type 4516

Maximum Overall Length
(Excluding semiflexible leads) . . . . . 3.94 in (10 cm)

Maximum Diameter . . . . . 0.78 in (2 cm)

Bulb T6

Base . . . . . See Dimensional Outline

Magnetic Shield . . . . . Millen[c] Part No.80801N, or equivalent

Operating Position . . . . . Any

Weight (Approx.) . . . . . 0.9 oz (25.5 g)

GENERAL (Cont'd)

Type 4517

Maximum Overall Length . . . . . 4.57 in (116 mm)
Seated Length . . . . . 3.88 in ± 0.19 in (98.6 mm ± 4.8 mm)
Maximum Diameter . . . . . 1.56 in (39.6 mm)
Bulb T12
Base . . . . . Small-Shell Duodecal 12-pin, JEDEC No.B12-43
Socket . . . . . Eby[b] No.9058, or equivalent
Magnetic Shield . . . . . Millen[c] No.80802C, or equivalent
Operating Position . . . . . Any
Weight (Approx.) . . . . . 2 oz

MAXIMUM RATINGS, *Absolute-Maximum Values*

DC Supply voltage:		
Between anode and cathode	1800 max.	V
Between anode and dynode No.10		
Type 4516	300 max.	V
Type 4517	250 max.	V
Between consecutive dynodes	300 max.	V
Between dynode No.1 and cathode		
Type 4516	300 max.	V
Type 4517	400 max.	V
Average Anode Current[e]	0.5 max.	mA
Ambient-Temperature Range[f]	-100 to +85	°C

CHARACTERISTICS RANGE VALUES

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

With E = 1500 volts (Except as noted)

	Min.	Typical	Max.	
Anode Sensitivity:				
Radiant[g] at 4000 angstroms	–	5.6×10^4	–	A/W
Luminous[h] (2870° K)				
Type 4516	10	47	170	A/lm
Type 4517	10	47	150	A/lm

→CHARACTERISTICS RANGE VALUES (Cont'd)

	Min.	Typical	Max.	
Current with blue light source[j] (2870°K + C.S. No.5-58)				
Type 4516	1.5×10^{-6}	7×10^{-6}	2.6×10^{-5}	A
Type 4517	1.5×10^{-5}	7×10^{-5}	2.2×10^{-4}	A
Cathode Sensitivity:				
Type 4516				
Radiant[k] at 4000 angstroms	–	0.071	–	A/W
Luminous[m] (2870°K)	5.3×10^{-5}	6×10^{-5}	–	A/lm
Current with blue light source[n] (2870° K + C.S. No.5-58)	8×10^{-9}	9×10^{-9}	–	A
Quantum Efficiency at 4000 angstroms	–	22	–	%
Type 4517				
Radiant[k] at 4000 angstroms	–	0.079	–	A/W
Luminous[m] (2870°K)	–	6.7×10^{-5}	–	A/lm
Current with blue light source[n] (2870° K + C.S. No.5-58)	8×10^{-10}	1×10^{-9}	–	A
Quantum Efficiency at 4000 angstroms	–	24	–	%
Type 4516				
Current Amplification	–	8×10^{5}	–	
Anode Dark Current at 7 A/lm[p]	–	2×10^{-10}	6×10^{-10}	A
Equivalent Anode Dark Current Input at 7 A/lm	–	2.9×10^{-11}[p]	8.6×10^{-11}[p]	lm
	–	2.4×10^{-14}[q]	7.2×10^{-14}[q]	W
Equivalent Noise Input[r]	–	4.1×10^{-13}	–	lm
	–	3.5×10^{-16}[s]	–	W
Dark Pulse Summation:[t]				
1 to 32 photoelectrons (See *Typical Dark-Pulse Spectrum*)	–	250	–	cps
Pulse Height Resolution[u]	–	8.5	–	%
Anode-Pulse Rise Time[v,w] at 1800 V	–	1.7×10^{-9}	–	s
Electron Transit Time[v,x] at 1800 V	–	1.8×10^{-8}	–	s

→Indicates a change or addition.

CHARACTERISTIC RANGE VALUES (Cont'd)

Type 4517	Min.	Typical	Max.	
Current Amplification . .	–	7×10^{5}	–	
Anode Dark Current at 7 A/lm[p]	–	2×10^{-10}	7×10^{-10}	A
Equivalent Anode Dark Current Input at 7 A/lm	–	2.9×10^{-11}[p]	1×10^{-10}[p]	lm
	–	2.4×10^{-13}[q]	8.4×10^{-12}[q]	W
Equivalent Noise Input[r] . .	–	3.9×10^{-13}	–	lm
	–	3.3×10^{-16}[s]	–	W
Dark Pulse Summation:[t]				
1 to 32 photoelectrons . (See *Typical Dark-Pulse Spectrum*)	–	250	–	cps
Pulse Height Resolution[u]	–	8.5	–	%
Anode-Pulse Rise Time[v,w] at 1800 V	–	2.1×10^{-9}	–	s
Electron Transit Time[v,x] at 1800 V	–	2.4×10^{-8}	–	s

Typical Potential Distribution Between:	Type 4516 8.25% of Supply Voltage (E) Multiplied by:	Type 4517 8.13% of Supply Voltage (E) Multiplied by:
Cathode and Dynode No.1	1.2	1.7
Dynode No.1 and Dynode No.2	1.2	1.3
Dynode No.2 and Dynode No.3	1.7	1.3
Dynode No.3 and Dynode No.4	1.0	1.0
Dynode No.4 and Dynode No.5	1.0	1.0
Dynode No.5 and Dynode No.6	1.0	1.0
Dynode No.6 and Dynode No.7	1.0	1.0
Dynode No.7 and Dynode No.8	1.0	1.0
Dynode No.8 and Dynode No.9	1.0	1.0
Dynode No.9 and Dynode No.10	1.0	1.0
Dynode No.10 and Anode	1.0	1.0
Anode and Cathode	12.1	12.3

[a] Made by Corning Glass Works, Corning, NY 14830.

[b] Made by Hugh H. Eby Company, 4701 Germantown Avenue, Philadelphia, PA 19144.

[c] Made by James Millen Manufacturing Company, 150 Exchange Street, Malden, MA 02148.

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 1190 lumens per watt.

h These values are calculated as shown below:

$$\text{Luminous Sensitivity (A/lm)} = \frac{\text{Anode Current (with blue light source) (A)}}{0.15 \times \text{Light Flux of } 1 \times 10^{-5} \text{ (lm)}}$$

The value of 0.15 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 1×10^{-5} lumen.

k This value is calculated from the typical cathode luminous sensitivity rating using a conversion factor of 1190 lumens per watt.

m This value is calculated as shown below:

$$\text{Cathode Luminous Sensitivity (A/lm)} = \frac{\text{Cathode Current (with blue light source) (A)}}{0.15 \times \text{Light Flux of } 1 \times 10^{-4}}$$

The value of 0.15 is the average value of 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 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 1×10^{-4} lumen and 200 volts are applied between cathode and all other electrodes connected as anode.

p 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 10 microamperes. Sensitivity of the tube under these conditions is approximately equivalent to 7 amperes per lumen. Dark current is measured with no light incident on the tube.

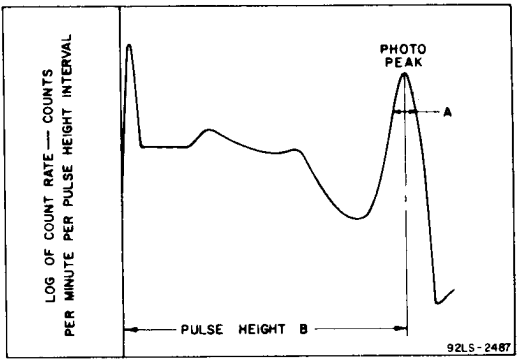
q At 4000 angstroms. These values are calculated from the EADCI values in lumens using a conversion factor of 1190 lumens per watt.

r 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.

s At 4000 angstroms. This value is calculated from the ENI value in lumens using a conversion factor of 1190 lumens per watt.

t Measured 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.

u The 662 keV photon from an isotope of cesium having an atomic mass of 137 (Cs^{137}) and a cylindrical 1-1/2" x 1-1/2" thallium-activated sodium-iodide scintillator [NaI (Tl) -type 6D6] are used. This scintillator is manufactured by the Harshaw Chemical Corporation, 1945 East 97 Street, Cleveland 6, OH 44106, and is rated by the manufacturer as having a resolution capability of 8.5%. 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 48640, 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).



v 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.

w 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.

x 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

SHIELDING

Electrostatic shielding of the 4516 and 4517 is ordinarily required. When a shield is used, it must be connected to the cathode terminal.

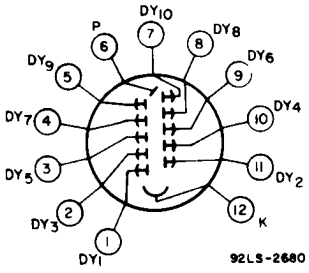
Magnetic shielding of the 4516 and 4517 is ordinarily required. See accompanying curves for the effect of variation in magnetic field intensity on the anode current for a tube with no magnetic shielding.

OPERATING VOLTAGES

In general, the operating potential between anode and cathode should not be less than 500 volts. The suggested voltage distribution shown in Table I is a typical, average distribution for obtaining a good compromise between output current and time and energy resolution. However, it may be necessary to individually adjust these distribution voltages by as much as ±15% to obtain optimum current amplification, pulse-height resolution, or time resolution.

LEAD CONNECTIONS (4516)

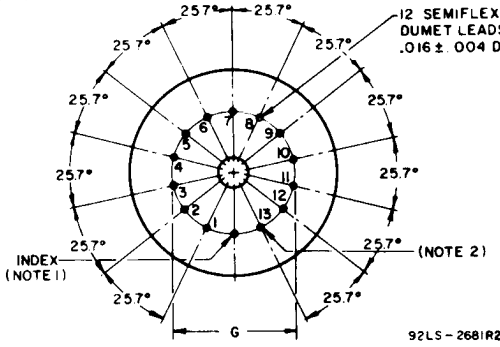
Bottom View



Lead 1: Dynode No.1
Lead 2: Dynode No.3
Lead 3: Dynode No.5
Lead 4: Dynode No.7
Lead 5: Dynode No.9
Lead 6: Anode
Lead 7: Dynode No.10
Lead 8: Dynode No.8
Lead 9: Dynode No.6
Lead 10: Dynode No.4
Lead 11: Dynode No.2
Lead 12: Photocathode

LEAD ORIENTATION (4516)

Bottom View



Note 1: Lead No.14 is cut off within 0.04 inch of the glass button for indexing.

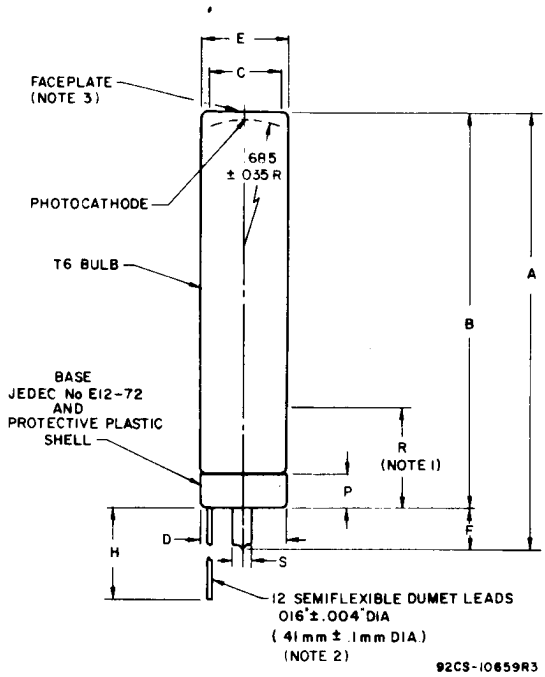
Note 2: Lead No.13 is cut off within 0.04 inch of the glass button.

OUTLINE DIMENSIONS (4516)

Dimensions	Inches	mm
A	3.94 max.	100.0 max.
B	$3.50^{+.06}_{-.12}$	$88.9^{+1.5}_{-3}$
C	.5 min. dia.	12.7 min. dia.
D	.78 max. dia.	19.8 max. dia.
E	.755 max. dia.	19.18 max. dia.
F	.38 max.	9.7 max.
G	.47 ± .01 dia.	11.9 ± .25 dia.
H	.75 min.	19.0 min.
P	.30 max.	7.6 max.
R	1.0 max.	25 max.
S	.17 max.	4.3 max.

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

DIMENSIONAL OUTLINE (4516)

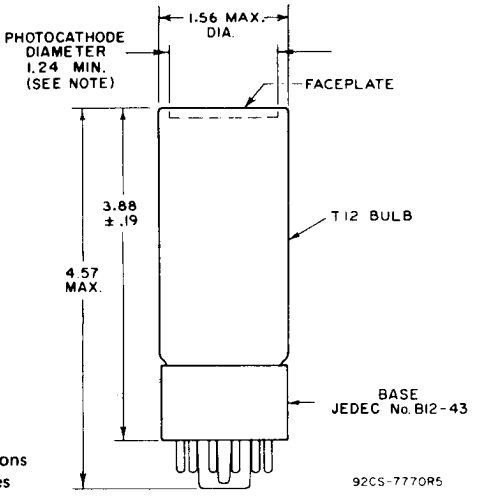


Note 1: Within this length, maximum diameter of tube is 0.78".

Note 2: The semiflexible leads of the tube may be soldered or welded into the associated circuit. If desired, the leads may be trimmed to within 1/4 inch of the protective shell. Care must be exercised when making such connections to prevent tube destruction due to thermal stress of the glass-metal seals. A heat sink placed in contact with the semiflexible leads between the point being soldered, or welded, and the protective shell is recommended. Excessive bending of the leads is to be avoided.

Note 3: Deviation from flatness will not exceed 0.006" from peak to valley.

DIMENSIONAL OUTLINE (4517)



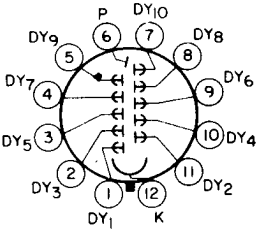
Note: Deviation from flatness will not exceed 0.010" from peak to valley.

℄ of bulb will not deviate more than 2° in any direction from the perpendicular erected at the center of bottom of the base.

PIN CONNECTIONS (4517)

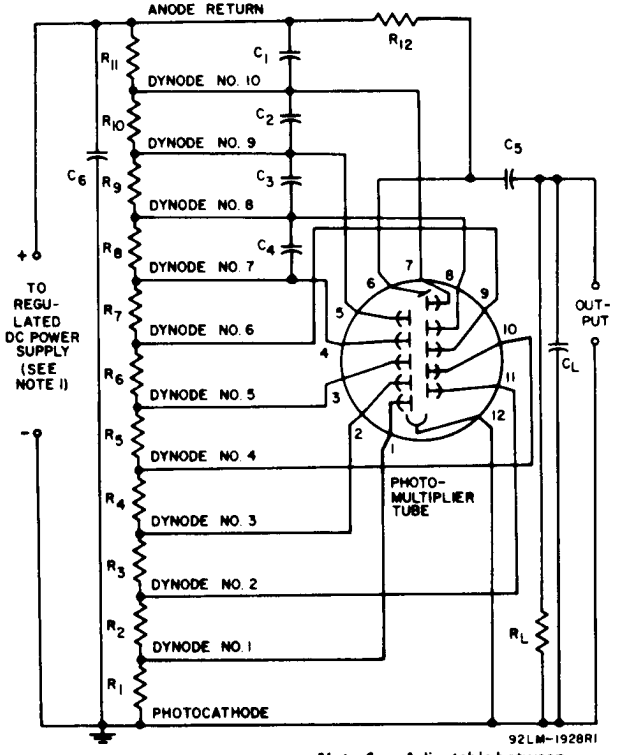
Bottom View

DIRECTION OF LIGHT: INTO END OF BULB



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: Anode
Pin 7: Dynode No.10
Pin 8: Dynode No.8
Pin 9: Dynode No.6
Pin 10: Dynode No.4
Pin 11: Dynode No.2
Pin 12: Photocathode

TYPICAL VOLTAGE-DIVIDER ARRANGEMENT FOR USE IN SCINTILLATION-COUNTING APPLICATIONS (4516, 4517)



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 V
R_1 and R_2: 560,000 ohms, 1/2 watt
R_3: 820,000 ohms, 1/2 watt
R_4 through R_{11}: 470,000 ohms, 1/2 watt
R_{12}: 1 megohm, 1/2 watt
R_{13}: 100,000 ohms, 1/2 watt

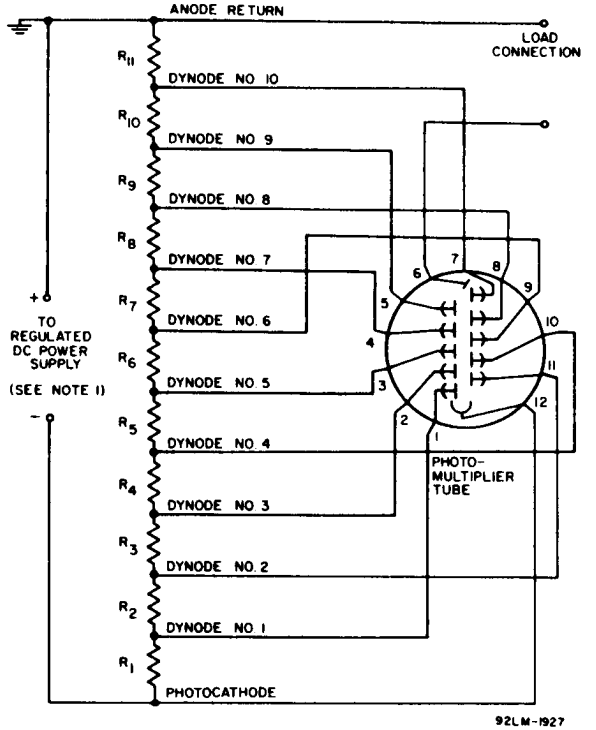
Note 1: Adjustable between approximately 500 and 1800 V dc.

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

Note 3: Component values are dependent upon nature of application and output signal desired.

Note 4: The value of the load elements, R_L and C_L, depend on the application:
$R_L C_L$ = 10 microseconds for most applications

TYPICAL VOLTAGE-DIVIDER ARRANGEMEN WHICH PERMITS DIRECT COUPLING TO THE ANODE (4516, 4517)

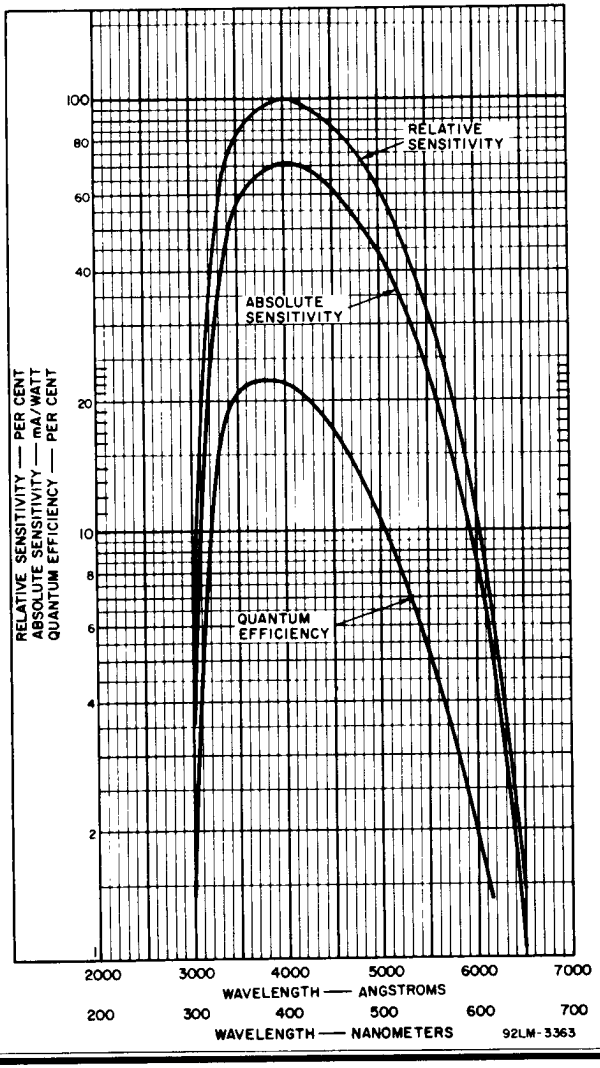


R_1 and R_2: 560,000 ohms, 1/2 watt
R_3: 820,000 ohms, 1/2 watt
R_4 through R_{11}: 470,000 ohms, 1/2 watt

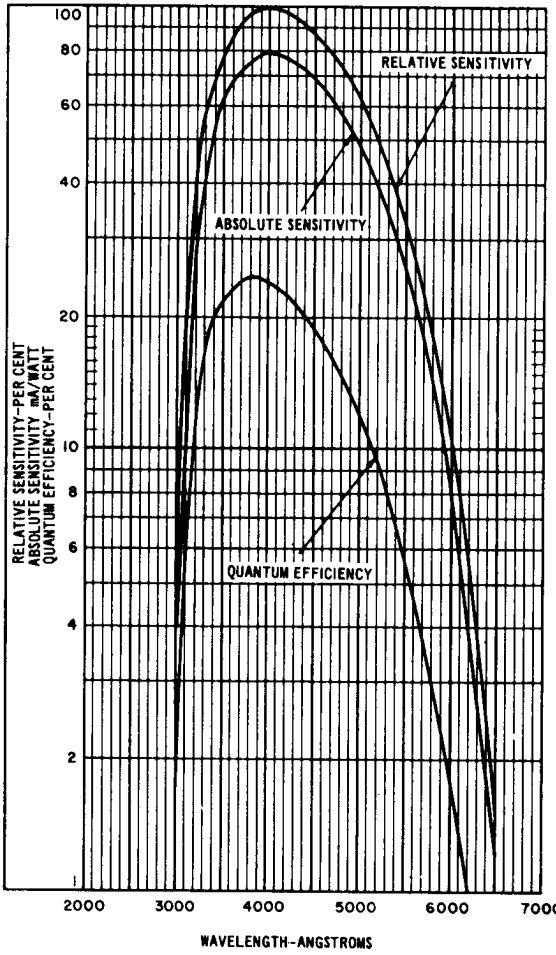
Note 1: Adjustable between approximately 500 and 1800 volts dc.

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

TYPICAL SPECTRAL RESPONSE CHARACTERISTICS (4516)



TYPICAL PHOTOCATHODE SPECTRAL RESPONSE CHARACTERISTICS (4517)



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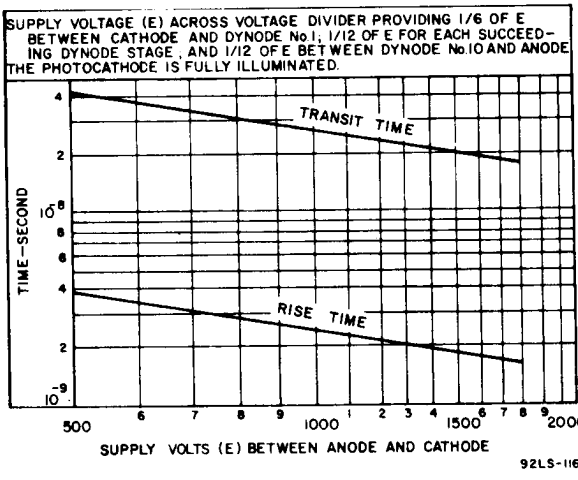
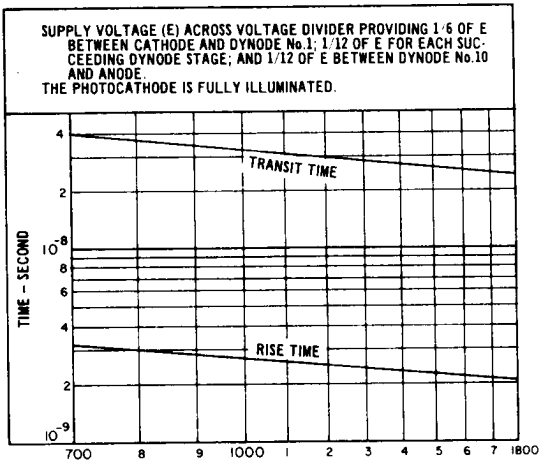
TYPICAL TIME-RESOLUTION CHARACTERISTICS

TYPE 4516



TYPE 4517

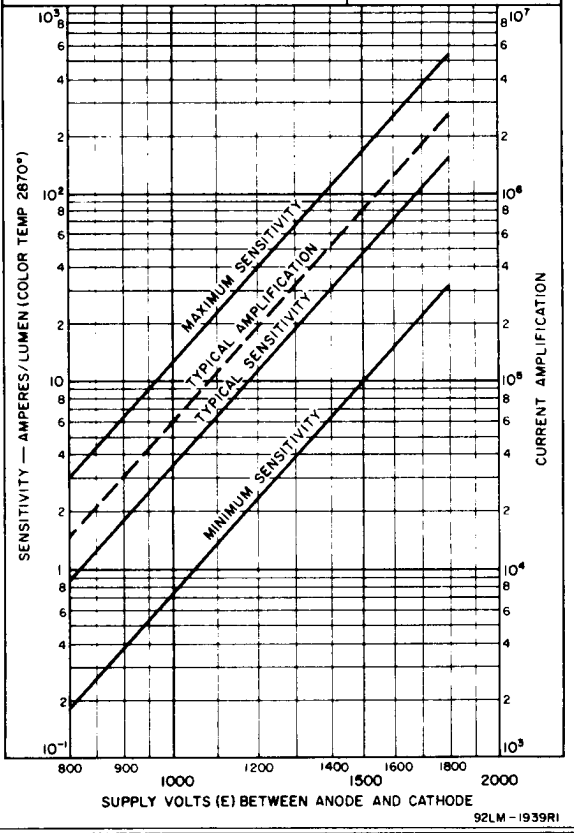


SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS

TYPE 4516

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

BETWEEN	8.25% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	1.2
DYNODE No. 1 AND DYNODE No. 2	1.2
DYNODE No. 2 AND DYNODE No. 3	1.7
EACH SUCCEEDING DYNODE STAGE	1.0
ANODE AND CATHODE	12.1

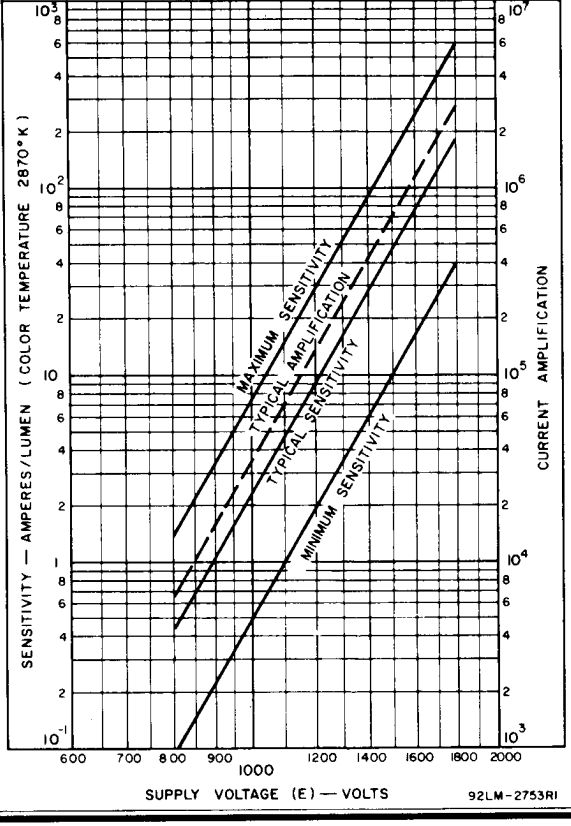


TYPICAL SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS

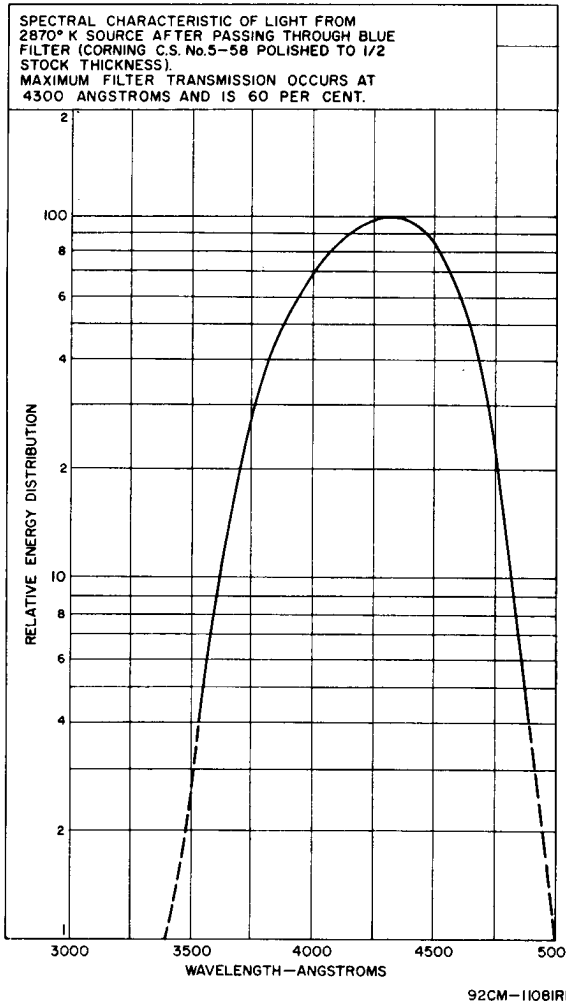
TYPE 4517

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

BETWEEN:	8.13 % OF (E) MULTIPLIED BY
CATHODE AND DYNODE No. 1	1.7
DYNODE No. 1 AND DYNODE No. 2	1.3
DYNODE No. 2 AND DYNODE No. 3	1.3
EACH SUCCEEDING DYNODE-STAGE	1.0
ANODE AND CATHODE	12.3



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



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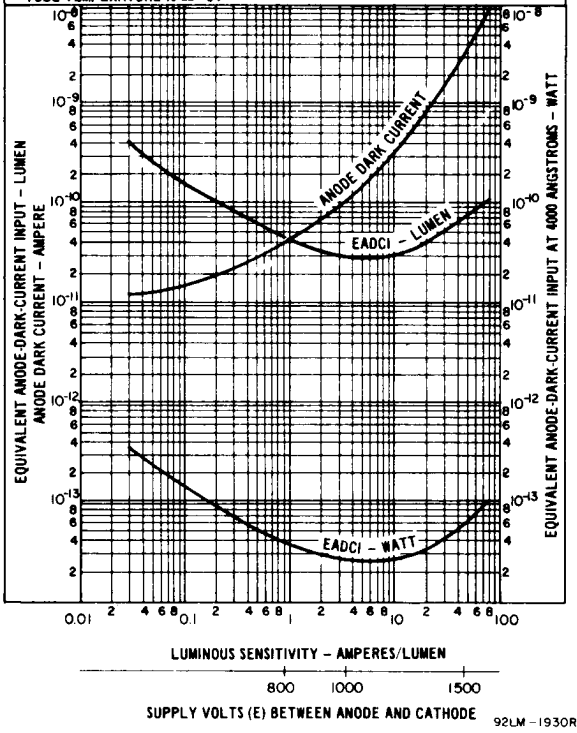
TYPICAL ANODE DARK CURRENT AND EADCI CHARACTERISTICS

TYPE 4516

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

BETWEEN	8.25% OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	1.2
DYNODE No. 1 AND DYNODE No. 2	1.2
DYNODE No. 2 AND DYNODE No. 3	1.7
EACH SUCCEEDING DYNODE-STAGE	1.0
ANODE AND CATHODE	12.1

TUBE TEMPERATURE IS 22° C.



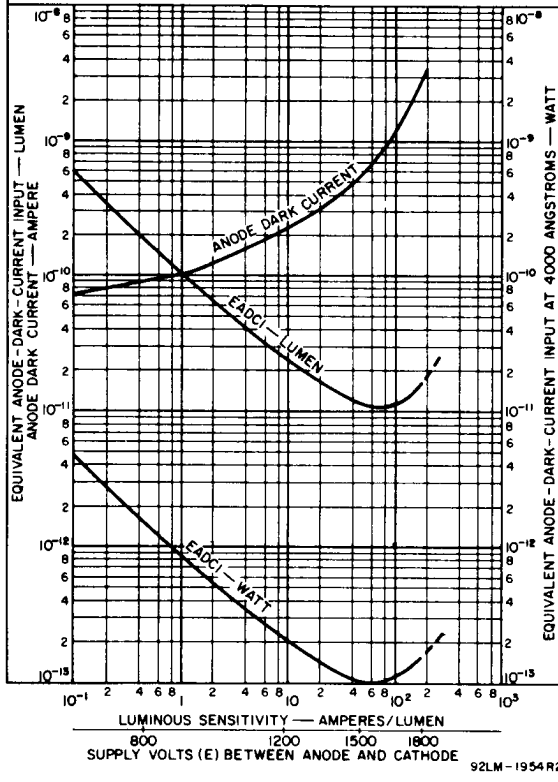
TYPICAL DARK CURRENT AND EADCI CHARACTERISTICS

TYPE 4517

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

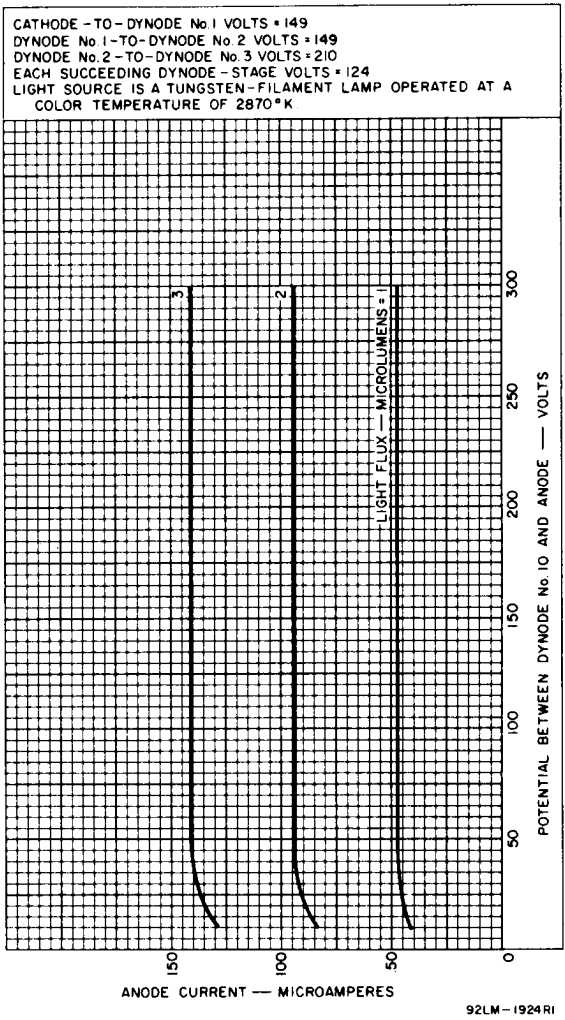
BETWEEN	8.13 % OF E MULTIPLIED BY
CATHODE AND DYNODE No. 1	1.7
DYNODE No. 1 AND DYNODE No. 2	1.3
DYNODE No. 2 AND DYNODE No. 3	1.3
EACH SUCCEEDING DYNODE STAGE	1.0
ANODE AND CATHODE	12.3

TUBE TEMPERATURE = 22°C



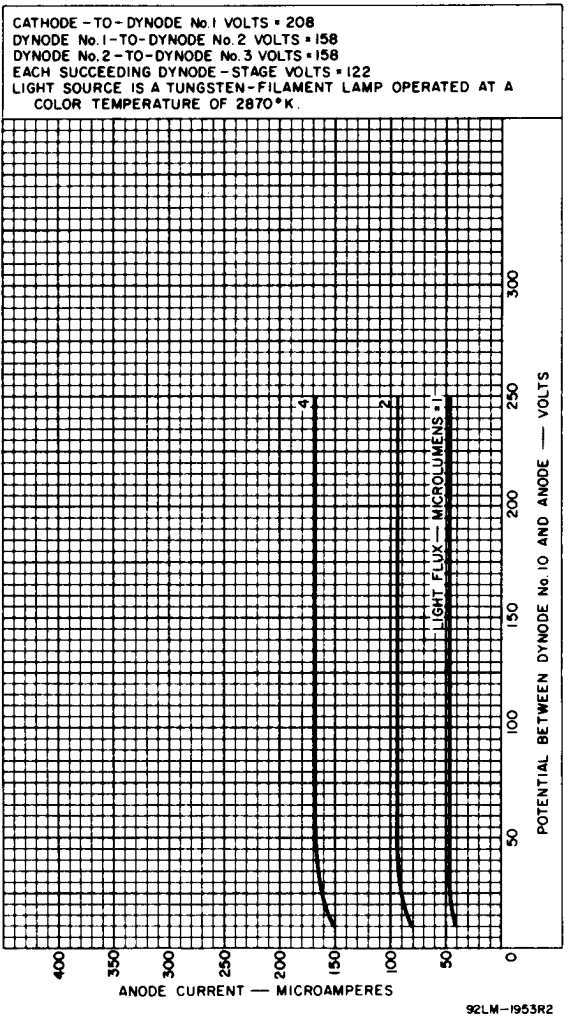
TYPICAL ANODE CHARACTERISTICS

TYPE 4516



TYPICAL ANODE CHARACTERISTICS

TYPE 4517



92LM-1953R2

TYPICAL DARK-PULSE SPECTRUM

	4516	4517
CATHODE-TO-DYNODE No.1 VOLTS	149	208
DYNODE No.1-TO-DYNODE No. 2 VOLTS	149	158
DYNODE No. 2-TO-DYNODE No. 3 VOLTS	210	158
EACH SUCCEEDING DYNODE-STAGE VOLTS	124	122
ANODE-TO-CATHODE VOLTS	1500	1500

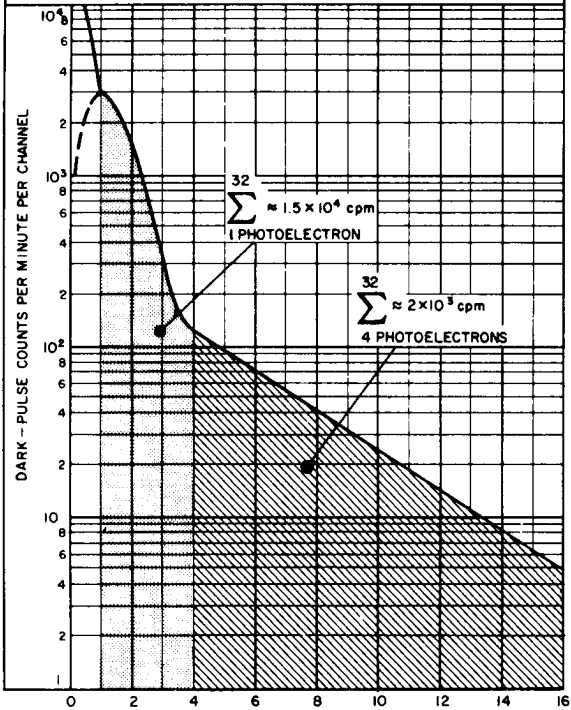
DASHED PORTION INDICATES LOCATION OF SINGLE PHOTOELECTRON PEAK. THIS PORTION OF CURVE IS NORMALIZED TO COINCIDE WITH SINGLE PHOTOELECTRON PEAK OF DARK PULSE SPECTRUM AND IS OBTAINED WITH PHOTOCATHODE FULLY ILLUMINATED BY A TUNGSTEN-FILAMENT LAMP OPERATED AT A LOW COLOR TEMPERATURE. DARK PULSES ARE SUBTRACTED.

SOLID-LINE PORTION INDICATES DARK-PULSE SPECTRUM.

TUBE TEMPERATURE = 22°C

ONE PHOTOELECTRON PULSE HEIGHT = 4 COUNTING CHANNELS.

INTEGRATING TIME CONSTANT = 30μ SEC. (R_L = 300kΩ C = 100 pF).



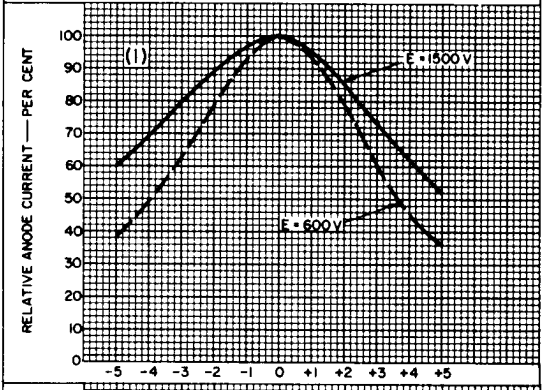
92LM-1940R2

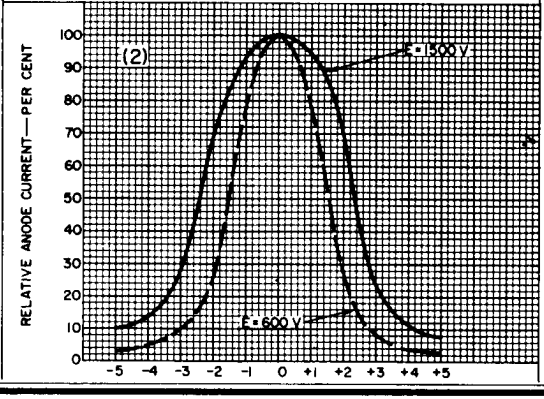
TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT

TYPE 4516

SUPPLY VOLTAGE (E) ACROSS 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.
PHOTOCATHODE IS FULLY ILLUMINATED.

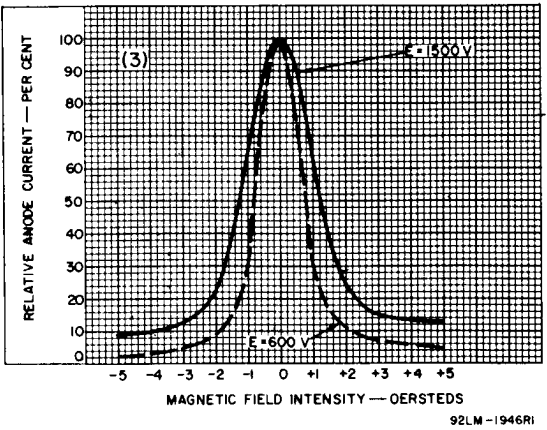
POSITIVE VALUES OF MAGNETIC FIELD INTENSITY (H) ARE FOR LINES OF FLUX IN INDICATED DIRECTION.
*POSITIVE VALUES OF MAGNETIC FIELD INTENSITY (H) ARE FOR LINES OF FLUX OUT OF PAPER.





TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT

TYPE 4516 (Cont'd)

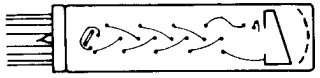


TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT

TYPE 4517

SUPPLY VOLTAGE E IS 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.

PHOTOCATHODE IS FULLY ILLUMINATED.
TUBE IS ORIENTED IN MAGNETIC FIELD AS SHOWN BELOW:

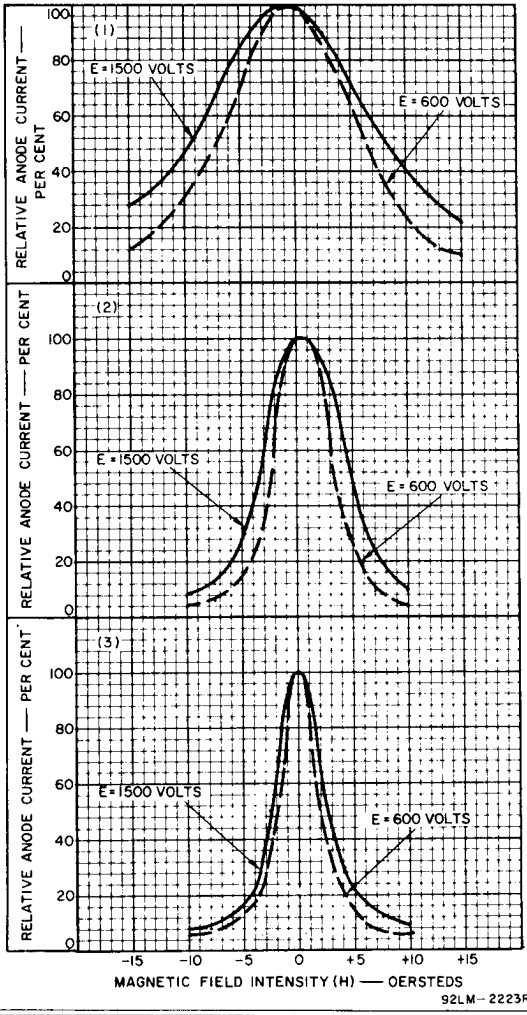


POSITIVE VALUE OF H IN DIRECTION SHOWN:
(1) →, (2) ↓, (3) ● *

* DIRECTION (3) IS OUT OF PAPER

TYPICAL EFFECT OF INDICATED MAGNETIC FIELD ON ANODE CURRENT

TYPE 4517 (Cont'd)



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