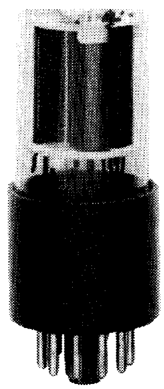
1P21
Photomultiplier



9-Stage, Side-Window Type With S-4 Spectral Response

- S-4 Spectral Response
- Circular-Cage Electrostatic Focus Type
- Low Dark Current -- 1 x 10^{-9} A at 20 A/lm and 22°C
- Fast Time Resolution Characteristics:
  Anode-Pulse Rise Time -- 1.6 x 10^{-9} second at 1250 volts
  Electron Transit Time -- 1.6 x 10^{-8} second at 1250 volts

BURLE 1P21 is a 9-stage, side-window type of photomultiplier tube intended for use in critical applications involving the detection and measurement of extremely low light levels. It features a combination of high photosensitivity and low dark current.

The 1P21 is recommended for use in photoelectric spectrometers, astronomical telescopes, and other types of equipment employing light beams that are essentially collimated.

General Data

Spectral Response	S-4
Wavelength of Maximum Response	380 nanometers
Cathode, Opaque	Cesium-Antimony
Minimum projected length[a]	23.9 mm (0.94 in)
Minimum projected width[a]	7.9 mm (0.31 in)
Window	Lime Glass (Corning[b] No.0080), or equivalent
Index of refraction at 436 nanometers	1.523
Dynodes:	
Substrate	Nickel
Secondary-Emitting Surface	Cesium-Antimony
Structure	Circular-Cage, Electrostatic-Focus Type
Direct interelectrode Capacitances (Approx.):	
Anode to dynode No.9	4.4 pF
Anode to all other electrodes	6.0 pF
Maximum Overall Length	93.5 mm (3.68 in)
Seated Length	79.2 mm (3.12 in)
Maximum Bulb Diameter	30.0 mm (1.18 in)
Base	Small-Shell Submagnal 11 Pin, (JEDEC Group 2, No.B11-88), Non-hygroscopic
Socket	BURLE AJ2256
Magnetic Shield	BURLE AJ2240
Operating Position	Any
Weight (Approx.)	45 g (1.6 oz)

Maximum Ratings, Absolute-Maximum Value[c]

DC or Peak AC Supply Voltage:		
Between anode and cathode	1250	V
Between anode and dynode No.9	250	V
Between consecutive dynodes	250	V
Between dynode No.1 and cathode	250	V
Average Anode Current[d]	0.1	mA
Ambient Temperature[e]	-80 to +85	°C

Performance Data

Under conditions with dc supply voltage (E) across a voltage divider providing **1/10** of E between cathode and dynode No.1 ; 1/10 of E for each succeeding dynode stage; and 1/10 of E between dynode No.9 and anode.

With E = 1000 volts (Except as noted)

	Min.	Typical	Max.	
Anode Sensitivity:				
Radiant at 380 nm	--	8.4 x 10^4	--	A/W
Luminous[f] (2856 K)	45	120	800	A/lm
Cathode Sensitivity:				
Radiant at 380 nm	--	38	--	mA/W
Luminous[g] (2856 K)	20	55	- -	uA/lm
Quantum Efficiency at 380 nm	--	12.4	--	%
Current Amplification	--	2.2 x 10^6	--	
Anode Dark Current[h]	--	1 x 10^{-9}	1 x 10^{-8}	A
Equivalent Anode Dark Current Input[h]	--	5 x 10^{-11}	5 x 10^{-10} --	lm
	--	4.8 x 10^{-14j}	4.8 x 10^{-13j}	W
Equivalent Noise Input (at 1000V)[k]	--	4.9 x 10^{-13}	--	lm
	--	7.1 x 10^{-16m}	--	W
Anode-Pulse Rise Time[n] at 1250 V	--	1.6x10^{-9}	--	s
Electron Transit Time[p] at 1250 V	--	1.6x10^{-8}	--	s

BURLE Electron Tubes

a On plane perpendicular to the indicated direction of incident light and passing through the major axis of the tube.

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

c 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.

d Averaged over any interval of 30 seconds maximum.

e Tube operation at room temperature or below is recommended.

f Under the following conditions: The light source is a tungsten-filament lamp having a lime-glass envelope. It is operated at a color temperature of 2856 K and a light input of 10 microlumens is used.

g Under the following conditions: The light source is a tungsten-filament lamp having a lime-glass envelope. It is operated at a color temperature of 2856 K. The value of light flux is 0.01 lumen and 100 volts are applied between cathode and all other electrodes connected as anode.

h At a tube temperature of 22°C. With supply voltage adjusted to give a luminous sensitivity of 20 amperes per lumen. Dark current caused by thermionic emission may be reduced by use of a refrigerant.

j At 380 nanometers.

k Under the following conditions: Tube temperature 22°C, external shield connected to cathode, bandwidth 1 Hz, tungsten-light source at a color temperature of 2856 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.

m At 380 nanometers.

n 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.

p 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 base pins of the 1P21 fit the submagnal 11-contact socket, such as the BURLE AJ2256, or equivalent. The socket should be made of high-grade, low-leakage material, and should be installed so that the base key of the tube faces the incident radiation.

Operating Stability

The operating stability of the 1P21 is dependent on the magnitude of the anode current. The use of an average anode current well below the maximum rated value of 0.1 milliampere is recommended when stability of operation is important. When maximum stability is required, operation at an average anode current of 1 microampere is suggested.

Ambient Atmosphere

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

Tube Orientation

The sensitivity of the photocathode surface varies with respect to the position of the light spot on the surface. **Figure 3a** shows the variation in sensitivity of the surface as the position of a 1 -mm diameter light spot is moved from one end of the photocathode to the other. Similarly, the curve in **Figure 3b** shows how the sensitivity of the photocathode surface varies across its projected width in the plane of the grill. From these curves, the equipment designer can readily determine the optimum position of any light spot on the photocathode surface to give the highest sensitivity.

When an application involves the use of light flux which covers essentially the entire cathode area, consideration should be given to the effect on luminous sensitivity caused by angular position of the cathode with respect to the direction of incident light. This effect is shown in **Figure 4.** As the tube is rotated from the position of maximum sensitivity (approximately + 13^{o} as shown in **Figure 4),** the internal structure prevents portions of a large beam of light from striking the cathode. With a light spot covering only a small portion of the cathode area, relatively minor cutoff of light occurs making the directional effect on luminous sensitivity very small.

Shielding

Electrostatic and/or magnetic shielding of the 1P21 may be necessary.

An external electrostatic shield, in contact with the sides of the glass envelope and connected to a negative dc potential essentially the same as that of the photocathode, should be employed in those applications where it is desired to reduce the equivalent noise input of the 1P21 to a minimum.

It is to be noted that the use of an external magnetic and/or electrostatic shield at high negative potential presents a safety hazard unless the shield is connected through a high impedance in the order of 10 megohms to the negative-potential source. If the shield is not so connected, extreme care should be observed in providing adequate safeguards to prevent personnel from coming in contact with the high potential of the shield.

Magnetic shielding of the 1P21 is necessary if it is operated in the presence of strong magnetic fields. The curve in **Figure 9** shows the effect on anode current of variation in magnetic field strength under the conditions indicated. With increase in supply voltage between anode and cathode, the effect of a given magnetic field will cause less decrease in anode current.

Adequate light shielding should be provided to prevent extraneous light from reaching any part of the 1P21.

Dynode Modulation

Current amplification may also be controlled or the output signal may be modulated by adjustment of the voltage applied to a single or two consecutive central dynodes with the voltages on the other stages held constant. The curve in **Figure 5a** shows the effect on output current as the voltage applied to dynode No.6 is varied. Similar results may be obtained by adjusting the voltage on dynodes No.2 and No.4. Somewhat less control is obtained by adjusting the voltage on dynodes No.3, No.5, or No.7.

The curve in Figure 5b shows the effect on output current as dynodes No.5 and No.6 are modulated simultaneously but with a constant 100 volt difference maintained between these dynodes during modulation. Similar results may be obtained by simultaneous modulation of dynode No.3 and No.4 and dynode No.7 and No. 8.

Dark Current

The use of a refrigerant, such as dry ice or liquid air, to cool the 1P21 is recommended in those applications where maximum current amplification with minimum dark current is required.

Typical ENI as a function of tube temperature is shown in Figure 7.

Typical anode dark current and EADCI as a function of luminous sensitivity at **a** temperature of +22° C is shown in Figure 8.

Operating Voltages

The recommended operating voltages for the 1P21 are as follows: the successive stages of the 1P21 are operated at voltages increasing in equal steps from the photocathode to the 9th dynode. The steps are generally chosen as 75 to 100 volts per stage. The operating voltage between dynode No.9 and anode should be kept as low as possible in order to reduce ohmic leakage current to the anode to a low level but large enough to take into account the voltage drop across a particular output load. For the higher light levels shown in Figure 11 for pulse service, higher voltage between dynode No.9 and anode will be required because of saturation due to space charge limitations.

In general, the current in the divider should be at least 10 times greater than the maximum average value of anode current. The resistance value of the voltage divider should be adequate to prevent variation of dynode potentials by signal current. Resistance values greaterthan 10 megohms should not be employed between adjacent tube elements. Location of the voltage divider arrangement should be such that the power dissipated in the resistor string does not increase the temperature of the tube.

A typical voltage divider arrangement for use with the 1P21 is shown in Figure 12. 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 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.

When the ratio of peak anode current to average anode current is high, non-inductive capacitors should be employed across the latter stages of the tube. The values of these capacitors should be chosen so that sufficient charge is available to prevent a change of more than a few per cent in interstage voltages throughout the pulse duration.

The high voltages at which these tubes are 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. Precautions should include the enclosure of high-potential 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.

In the use of the 1P21 as with other tubes requiring highvoltages, it should always be remembered that these high voltages may appear at points in the circuit which are normally at low potential because of defective circuit parts or incorrect circuit connections. Therefore, before any part of the circuit is touched, the power-supply switch should be turned off and both terminals of any capacitors grounded.

The capacitor values will depend upon the shape and 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:

$$C = 100 \frac{it}{V}$$

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 approximately 2 per stage is used. Capacitors are not required across those dynode stages where 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 (it) and the following formula applies:

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

where $q = \int i(t)\,dt$ coulombs

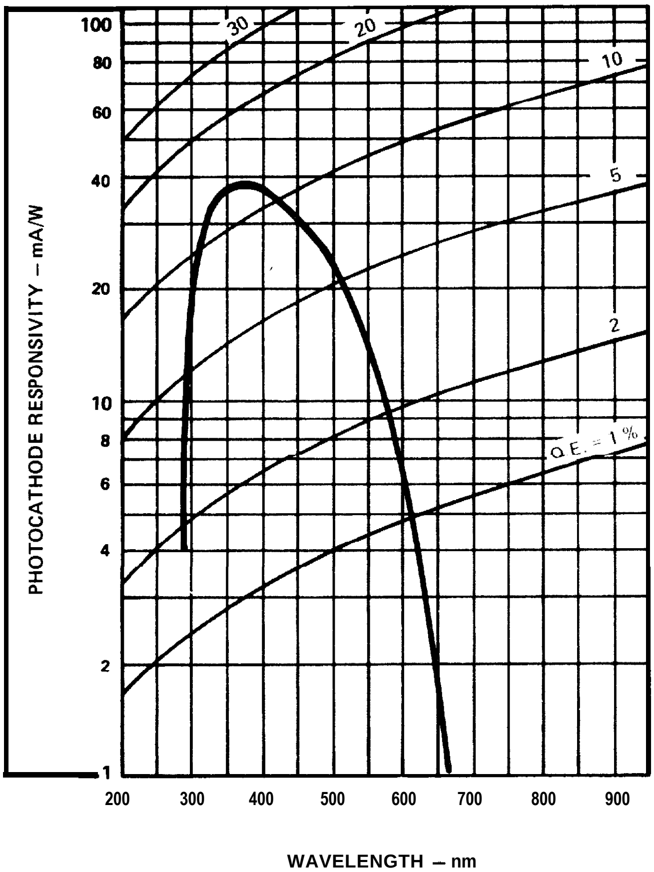


Figure 1 - Typical Spectral Response Characteristics

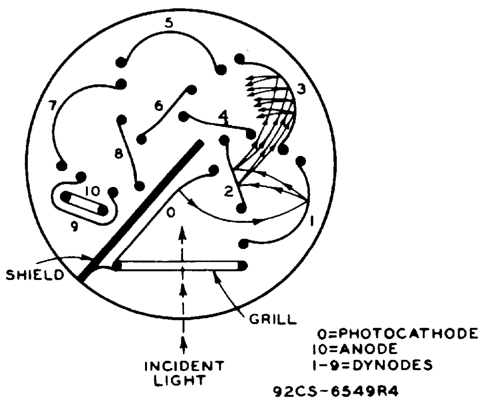


Figure 2 - Schematic Arrangement of Structure

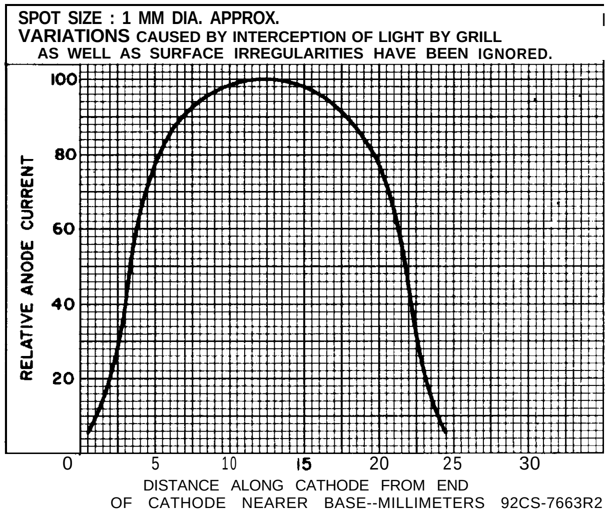


Figure 3a - Typical Variation of Photocathode Sensitivity Along Tube Length

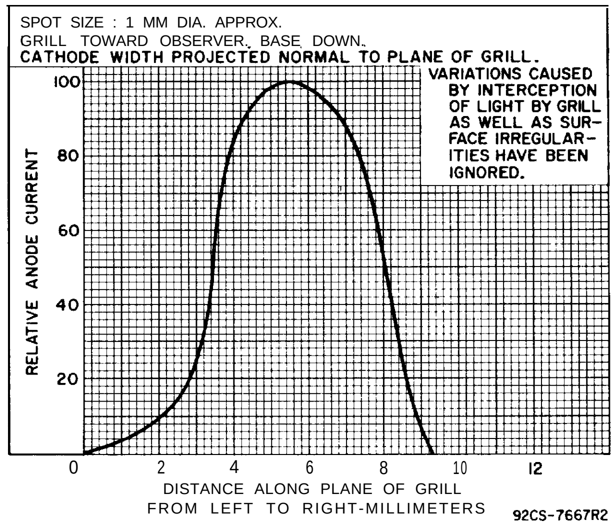


Figure 3b - Typical Variation of Photocathode Sensitivity Across Projected Width in Plane of Grill

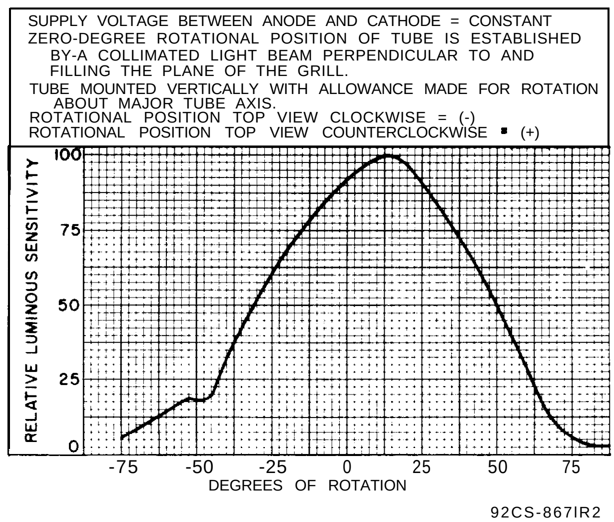


Figure 4 - Typical Variation of Sensitivity as Tube is Rotated With Respect to Fixed Light Beam

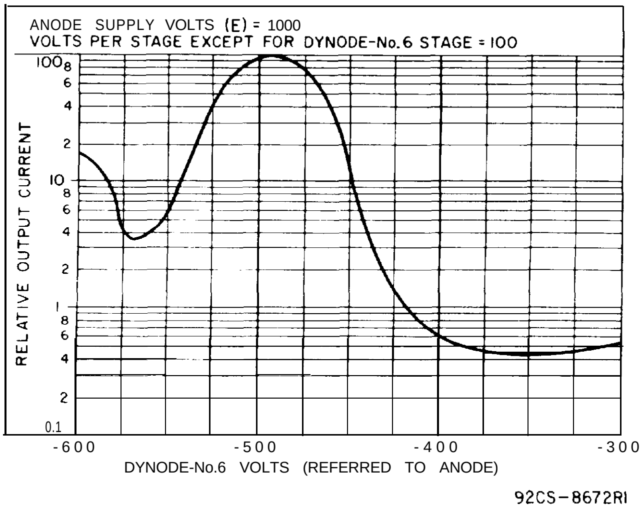


Figure 5a - Typical Characteristic of Output Current as a Function of Dynode-No.6 Volts

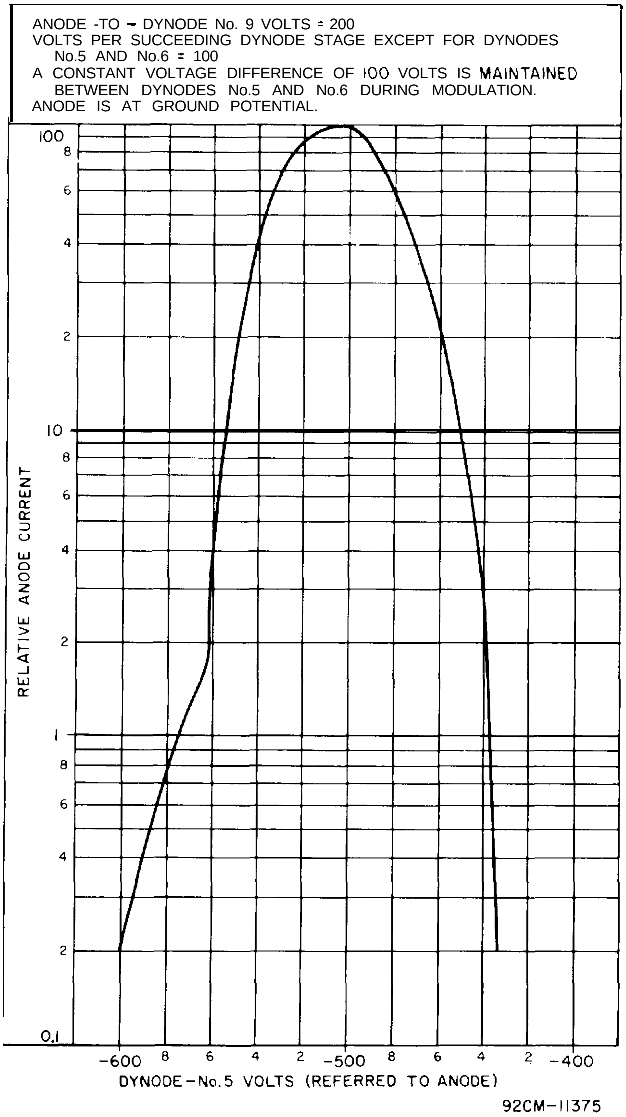


Figure 5b - Typical Characteristic of Output Current as a Function of Simultaneous Modulation of Dynodes No.5 and No.6

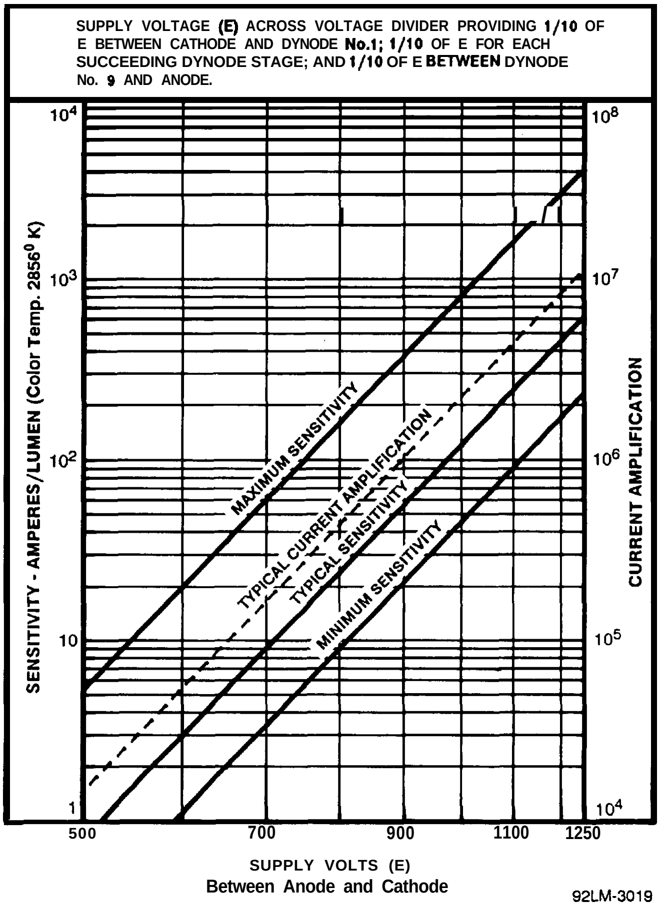


Figure 6 - Sensitivity and Current Amplification Characteristics

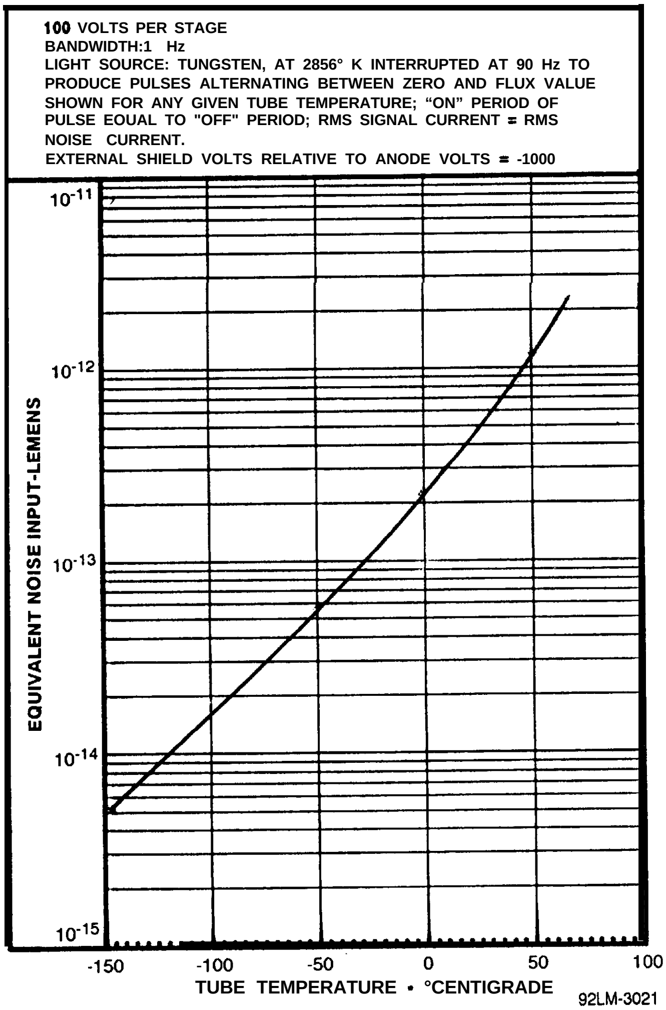


Figure 7 - ENI Characteristic as a Function of Tube Temperature

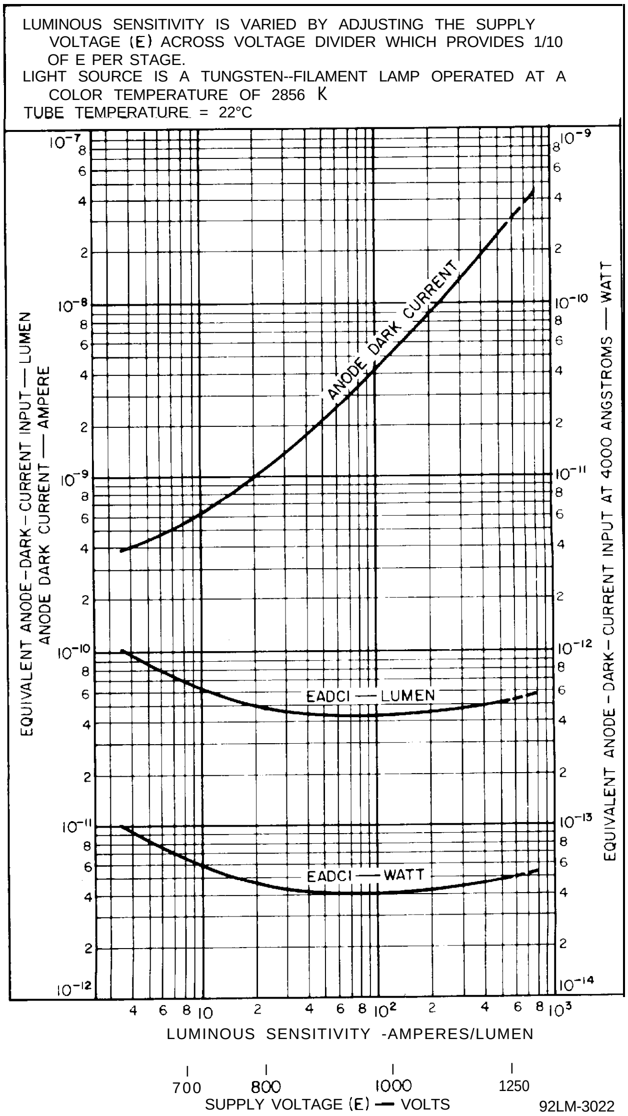


Figure 8 - Typical EADCI and Dark Current Characteristics

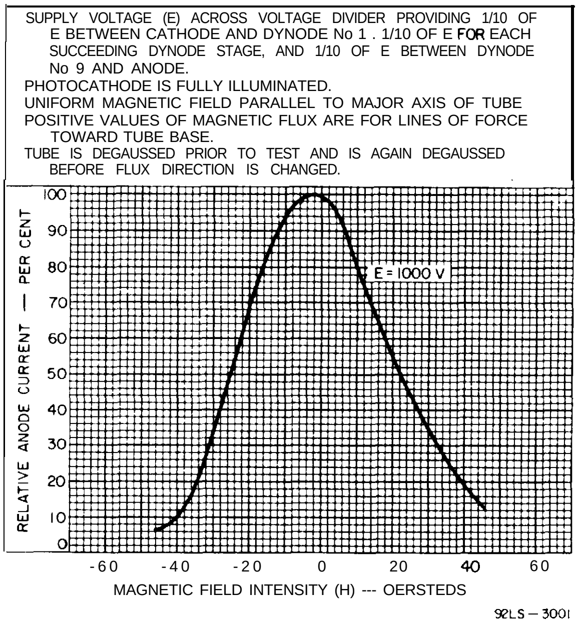


Figure 9 - Typical Effect of Magnetic Field on Anode Current

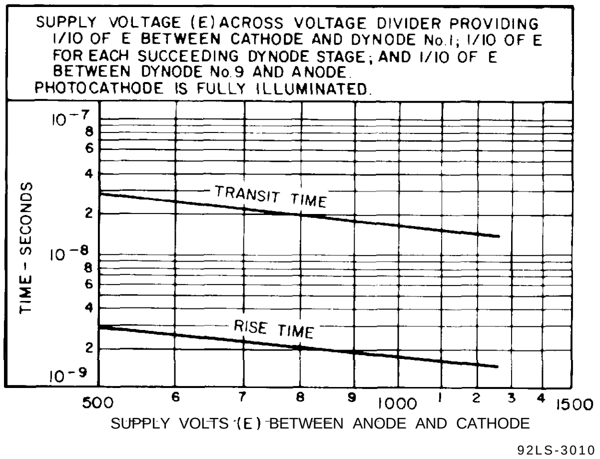


Figure 10 - Typical Time-Resolution Characteristics

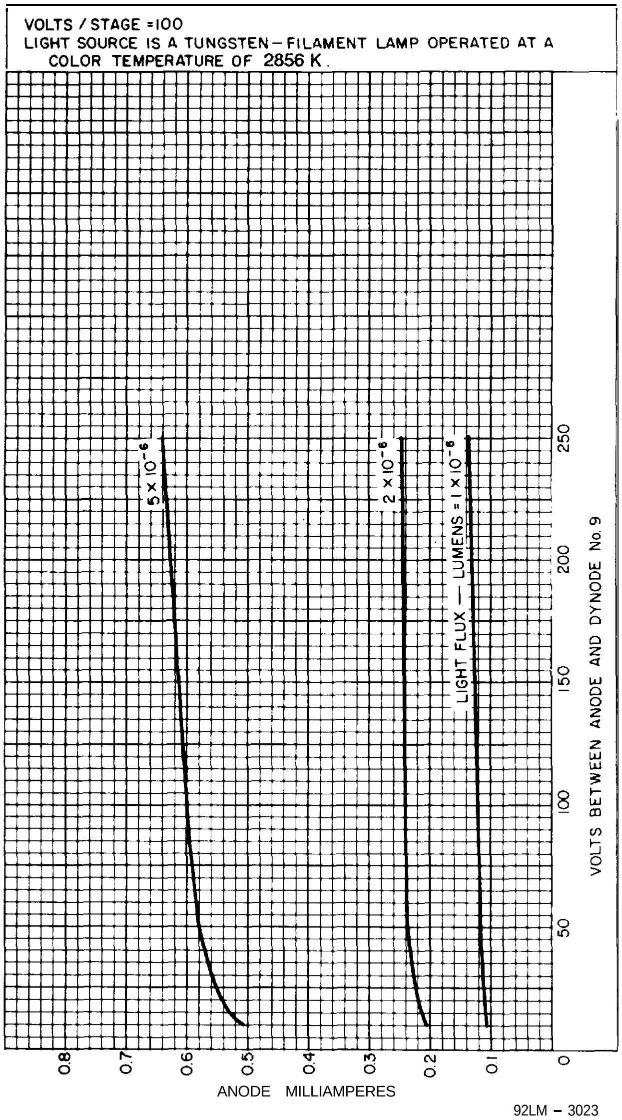
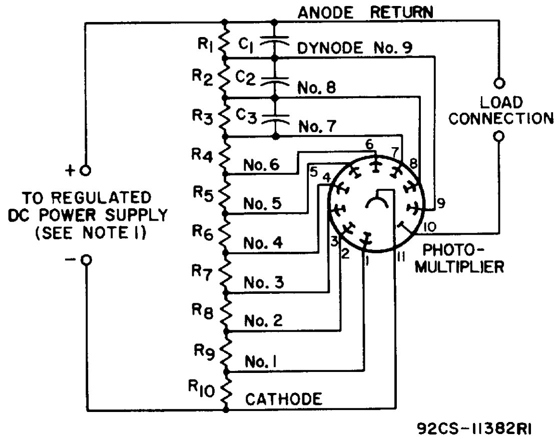


Figure 11 - Typical Anode Characteristics



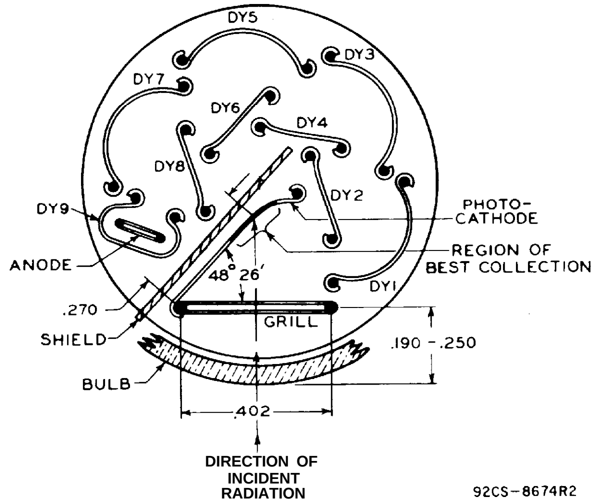
R_1 through R_{10} = 20,000 to 1,000,000 ohms

Note 1: Adjustable between approximately 500 and 1250 volts.

Note 2: Capacitors C_1 through C_3 should be connected at tube socket for optimum high-frequency performance.

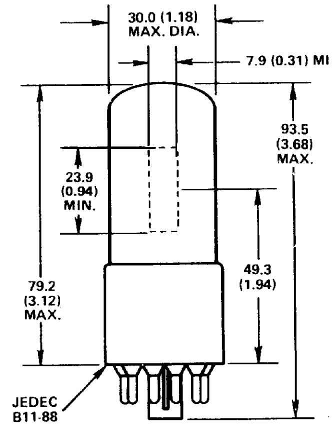
Leads to all capacitors should be as short as possible to minimize inductar.ce effects.

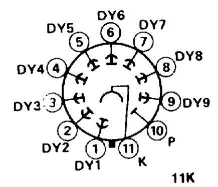
Figure 12 - Typical Voltage-Divider Arrangement



Dimensions in inches.

Top View





Dimensions in millimeters. Dimensions in parentheses are in inches.

Fiaure 13 - Dimensional Outline and Basing Diagram

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