Photomultiplier Tubes

3/4 Inch Diameter, 10-Stage, Head-On Types
Multialkali Photocathode of High Quantum Efficiency
In-Line Electrostatically-Focused Dynode Structure

For miniaturized low-level light detection and measurement systems and laser detection equipment to approximately 8000 angstroms. Typical quantum efficiency of these tubes at 6943 angstroms, is 2.5 per cent.

GENERAL

Spectral Response S-20
Wavelength of Maximum Response. . . . 4200 ± 500 angstroms
Cathode, Semitransparent . . . . . . Potassium-Sodium-Cesium-Antimony (Multialkali)
  Shape . . . . Sperical Section
  Minimum area . . . . 0.2 sq.in (129 sq.mm)
  Minimum diameter . . . . 0.5 in.(12.7 mm)
Window . . . . Borosilicate, Corning[a] No.7056, or equivalent
  Shape . . . . .Plano-Concave
  Index of refraction at 5893 angstroms 1.49
Dynodes:
  Substrate. . . . . Copper-Beryllium
  Secondary-Emitting Surface . . . . Beryllium-Oxide
  Structure . . . . In-Line Electrostatic-Focus Type
Direct Interelectrode Capacitances (Approx.):
  Anode to dynode No.10. . . . . 2.4 pF
  Anode to all other electrodes. . . . . 3.6 pF
Maximum Overall Length (Excluding leads):
  8644. . . . . 3.9 in (99 mm)
  8645. . . . . 4.55 in (115.6 mm)
Maximum Diameter:
  8644. . . . . 0.78 in (19.8 mm)
  8645. . . . . 0.95 in (24.1 mm)
Bulb. T6
Lead Connections . . . . (See *Dimensional Outline*)
Temporary Base . . . . .Small-Shell Duodecal, JEDEC B12-43
Magnetic Shield . . . . See footnote (b)
Operating Position . . . . Any
Weight (Approx.):
  8644
    With temporary base. . . . . 1.7 oz (48.2 g)
→ Without temporary base. . . . . .0.9 oz (25.5 g)
  8645. . . . . 4.5 oz (127.6 g)

→ Indicates a change.

ABSOLUTE-MAXIMUM RATINGS

	8644	8645	
Supply Voltage (DC or Peak AC):			
Between Anode and Cathode	2100 max.	1800 max.	V
Between Anode and Dynode No.10	300 max.	300 max.	V
Between Consecutive Dynodes	200 max.	–	V
Between Dynode No.1 and Cathode	400 max.	–	V
→ Average Anode Current[d]	0.5 max.	0.1 max.	mA
→ Ambient Temperature	85 max.	55 max.	°C

CHARACTERISTICS RANGE VALUES

→ *Under conditions with dc supply voltage (E) across a voltage divider as shown in Table I. This voltage distribution is provided by the integral voltage-divider network of type 8645.*

With E = 1500 volts dc *(Except as noted)*

For Both Types:	Min.	Typ.	Max.	
Sensitivity:				
Radiant, at 4200 angstroms	–	5.1×10^{3}	–	A/W
Cathode radiant, at 4200 angstroms	–	0.064	–	A/W
Luminous[f]	4	12	60	A/lm
Cathode luminous:				
With tungsten light source[g]	1.2×10^{-4}	1.5×10^{-4}	–	A/lm
With blue light source[h]	5.5×10^{-8}	8.5×10^{-8}	–	A
With red light source[i]	4×10^{-7}	5.2×10^{-7}	–	A
Current Amplification	–	8×10^{4}	–	
Equivalent Anode-Dark-Current Input[k,m]	–	4×10^{-11}	6×10^{-10}	lm
	–	9.4×10^{-14}[n]	1.4×10^{-12}[n]	W
→ Anode Dark Current[k,m]	–	1.2×10^{-9}	–	A
Equivalent Noise Input[p]	–	2.5×10^{-12}	–	lm
	–	6×10^{-15}[n]	–	W
Anode-Pulse Rise Time[q]	–	1.8×10^{-9}	–	s
Electron Transit Time[r]	–	2×10^{-8}	–	s

With E = 2000 volts dc *(Except as noted)*

For Type 8644 Only:	Min.	Typ.	Max.	
Sensitivity:				
Radiant, at 4200 angstroms	–	4.7×10^{4}	–	A/W

→ Indicates a change.

Cathode radiant, at 4200 angstroms	–	0.064	–	A/W
Luminous[f]	–	110	–	A/lm
Cathode luminous:				
With tungsten light source[g]	1.2×10^{-4}	1.5×10^{-4}	–	A/lm
With blue light source[h]	5.5×10^{-8}	8.5×10^{-8}	–	A
With red light source[i]	4×10^{-7}	5.2×10^{-7}	–	A
Current Amplification . .	–	7.3×10^{5}	–	
Equivalent Anode-Dark-Current Input[k,m]	–	4×10^{-11}	6×10^{-10}	lm
	–	9.4×10^{-14}[n]	1.4×10^{-12}[n]	W
Anode Dark Current	–	5×10^{-9}	–	A
Anode-Pulse Rise Time[q]	–	1.5×10^{-9}	–	s
Electron Transit Time[r]. .	–	1.7×10^{-8}	–	s

[a] Made by Corning Glass Works, Corning, New York.

[b] Magnetic shielding material, for type 8644, in the form of foil or tape as available from the Magnetic Shield Division, Perfection Mica Company, 1322 North Elston, Chicago 24, Illinois, or equivalent. Type 8645 has an integral magnetic shield.

[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 2870° K and a light input of 1 microlumen 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 2870° K. The value of light flux is 0.01 lumen and 200 volts are applied between cathode and all other electrodes connected as anode. This characteristic can not be measured after type 8645 is encapsulated in its potting compound.

[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—Manufactured by the Corning Glass Works, Corning, New York) from a tungsten-filament lamp operated at a color temperature of 2870° K. The value of light flux incident on the filter is 0.01 lumen and 200 volts are applied between cathode and all other electrodes connected as anode. This characteristic can not be measured after type 8645 is encapsulated in its potting compound.

[i] Under the following conditions: Light incident on the cathode is transmitted through a red filter (Corning C.S. No.2-62—Manufactured by the Corning Glass Works, Corning, New York) from a tungsten-filament lamp operated at a color temperature of 2870° K.

The value of light flux incident on the filter is 0.01 lumen and 200 volts are applied between cathode and all other electrodes connected as anode. This characteristic can not be measured after type 8645 is encapsulated in its potting compound.

[k] At a tube temperature of 22° C. Dark current may be reduced by use of a refrigerant.

[m] With supply voltage (E) adjusted to give a luminous sensitivity of 30 amperes per lumen.

[n] At 4200 angstroms. This value is calculated using a conversion factor of 428 lumens per watt.

[p] Under the following conditions: Supply voltage (E) is as shown, 22° C tube temperature, external shield connected to cathode, bandwidth 1 cycle per second, 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.

[q] 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.

[r] 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 and Mounting Considerations:

Type 8644

The 8644 is supplied with a small-shell duodecal base attached to semiflexible leads to facilitate testing. After testing, the attached base should be removed prior to installing the 8644 in a given system.

The *semiflexible leads* of the 8644 may be soldered or welded into the associated circuit. However, extreme caution must be exercised when making such connections to the leads 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 glass button is recommended.

Excessive bending of the leads—especially in the region close to the glass button—must be avoided.

Direct clamping to the bulb for mounting purposes is not recommended. It is suggested that a resilient material, such as Silastic* RTV 881, RTV 882, or equivalent, be used between the bulb and clamp.

The application of high voltage, with respect to cathode, to insulating or other materials supporting or shielding the 8644 at the photocathode end of the tube should not be permitted unless such materials are chosen to limit leakage current to the tube envelope to 1×10^{-12} ampere or less. In addition to increasing dark current and noise output because of voltage gradients developed across the bulb wall, such high voltage may produce minute leakage current to the cathode through the tube envelope and insulating materials which can permanently damage the tube.

Type 8645

Support for the 8645 may be effected by clamping directly to the magnetic shield. However, only that amount of uniformly distributed pressure necessary to hold the tube firmly in position should be employed.

Shielding:

Type 8644

Electrostatic and magnetic shielding of the 8644 is usually required. When a shield is used it must be at cathode potential.

See accompanying curves which show the effect of magnetic fields on anode current of the 8644 under the conditions indicated. The effects of hysteresis due to residual magnetism of the materials used in the tube structure have been neglected.

Type 8645

The 8645 is encapsulated with an insulating plastic potting compound in a magnetic shield and has

* Trademark of Dow Corning Corporation, Midland, Michigan.

an integral voltage-divider network. The magnetic shield is electrically connected to the photocathode.

See accompanying curve which shows the effect of magnetic fields on anode current of the 8645 under the conditions indicated. The effects of hysteresis due to residual magnetism of the materials used in the tube have been neglected.

See accompanying voltage-divider network and supply voltage connections for the 8645.

Dark Current:

A very small *anode dark current* is observed when voltage is applied to the electrodes of these tubes in complete darkness. Among the components contributing to dark current are ohmic leakage between the anode and adjacent elements and pulses produced by electrons thermionically released from the cathode, secondary electrons released by ionic bombardment of the dynodes, support rods, or cathode, and by cold emission from the electrodes.

Typical anode dark current as a function of luminous sensitivity at a temperature of +22^{o} C is shown in accompanying Typical-Dark Current and EADCI Characteristics.

A temporary increase in anode dark current by as much as 3 orders of magnitude may occur if these tubes are exposed momentarily to high-intensity ultraviolet radiation from sources such as fluorescent room lighting even though voltage is not applied to the tubes. The increase in dark current may persist for a period of 24 to 48 hours following such irradiation.

For *optimum tube performance* it is also recommended that the 8644 and 8645 be operated at or below room temperature. Dark current may be reduced by use of a refrigerant such as dry ice.

Operating Stability:

The operating stability of the 8644 and the 8645 is dependent on the magnitude of the anode current.

The use of an average anode current well below the maximum rated value of 0.5 milliampere is recommended when stability of operation is important. When maximum stability is required, operation at an average anode current of 0.5 microampere is recommended.

Operating Voltages:

The 8645 is supplied with an integral voltage-divider network. The following considerations, accordingly, apply only to type 8644.

The *voltage applied between cathode and dynode No.1* should be nearly constant and have a value of at least 150 volts to insure high conversion efficiency, i.e., high photon quantum efficiency, high collection efficiency, and high first dynode gain. Zener diodes, or other constant voltage sources, may be employed across these elements to provide constant voltage in applications where tube sensitivity is varied by adjusting the supply voltage.

The *operating voltage between dynode No.10 and anode* should be kept as low as will permit operation over the knee of the accompanying anode characteristic curves. With low operating voltage between dynode No.10 and anode, the ohmic leakage current to the anode is reduced. Operation over the knee occurs in the approximate range of 100 to 150 volts for the light level range shown. Under high pulse current conditions, saturation due to space-charge limitations will occur and higher voltage will be required. To obtain the suggested operating voltage between dynode No.10 and anode, it is necessary to increase the supply voltage between these electrodes by an amount equal to the voltage drop across a particular output load.

The *operating voltages* for the 8644 can be supplied by spaced taps on a voltage divider across a regulated dc power supply. The current through the voltage divider will depend on the applied voltage and the linearity required by the application. In general, the current in the divider should be at least 5 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 greater than 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. In pulse applications requiring low-noise operation, it is recommended that the *negative high-voltage terminal be* grounded.

See *Typical voltage-divider arrangement* for use with the 8644. 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 5 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 high-quality 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 the interstage voltages throughout the pulse duration.

Damping resistors in series with each of the dynode leads of the latter stages of the tube may be used to suppress spurious oscillations under high peak current conditions. Typical values for these resistors are in the range of 5 to 50 ohms. These values are chosen to provide sufficient damping while minimizing the voltage drop across the resistors.

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.

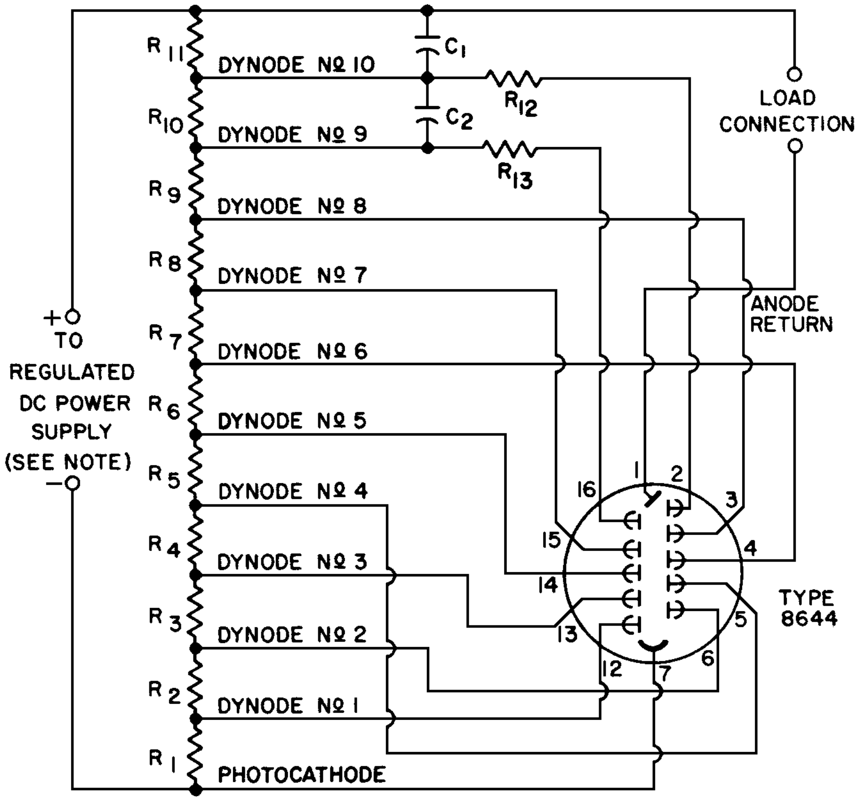
In the use of the 8644 and the 8645, as with other tubes requiring high voltages, it should always be remembered that these high voltages may appear at points in the circuit which are normally at low potential, because of defective circuit parts or incorrect circuit connections. Therefore, before any part of the circuit is touched, the power-supply switch should be turned off and both terminals of any capacitors grounded.

TABLE I

TYPICAL VOLTAGE DISTRIBUTION

Between:	8.33% of Supply Voltage (E) Multiplied by:
Cathode and Dynode No.1	1.1
Dynode No.1 and Dynode No.2	1.2
Dynode No.2 and Dynode No.3	1.7
Dynode No.3 and Dynode No.4	1.0
Dynode No.4 and Dynode No.5	1.0
Dynode No.5 and Dynode No.6	1.0
Dynode No.6 and Dynode No.7	1.0
Dynode No.7 and Dynode No.8	1.0
Dynode No.8 and Dynode No.9	1.0
Dynode No.9 and Dynode No.10	1.0
Dynode No.10 and Anode	1.0
Anode and Cathode	12.0

TYPICAL VOLTAGE-DIVIDER ARRANGEMENT FOR TYPE 8644



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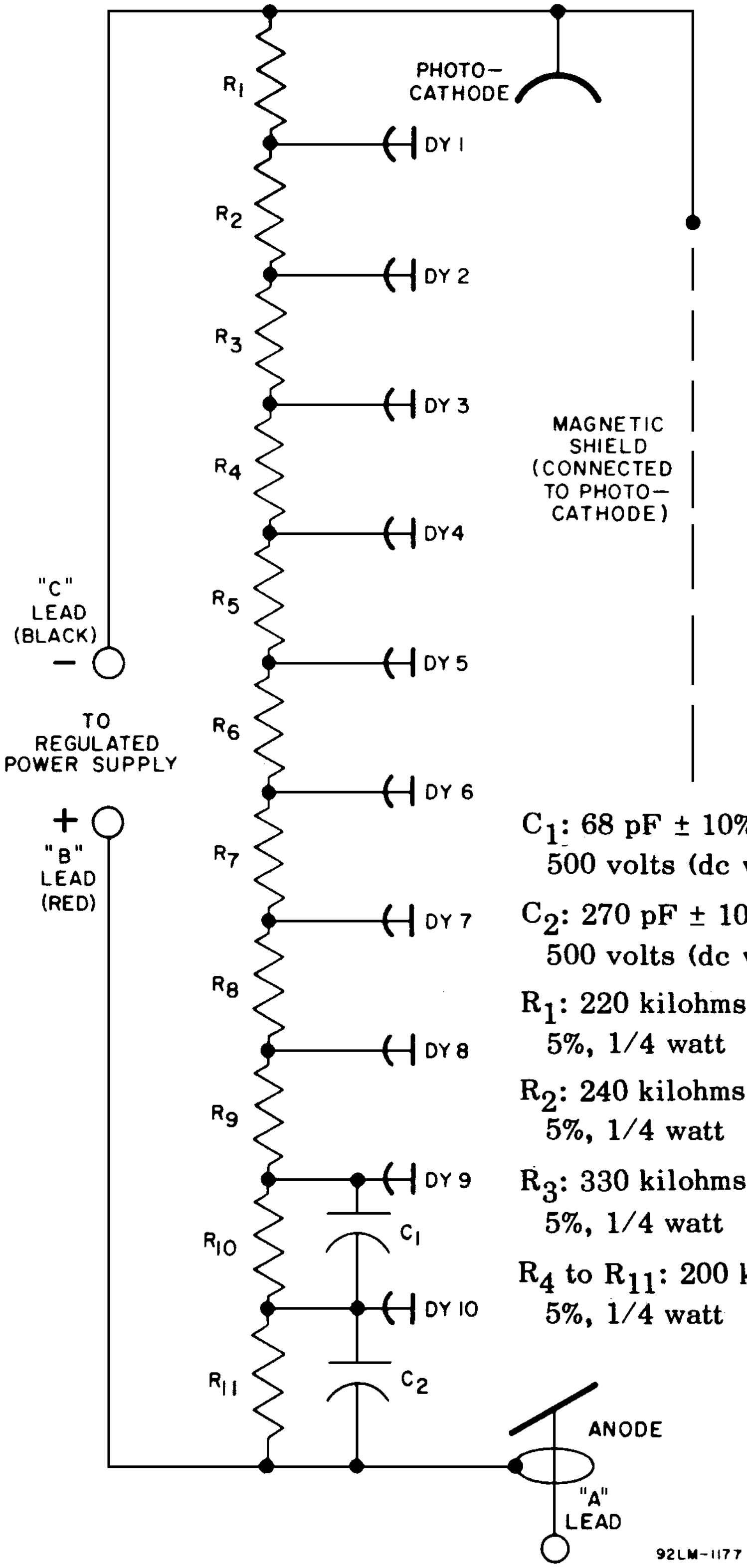
NOTE: Adjustable between approximately 500 and 2100 volts dc.

C_1, C_2: 0.01 µF, non-inductive type, 400 volts (dc working)

R_1: 51 kilohms, 5%, 1 watt
R_2: 56 kilohms, 5%, 1 watt
R_3: 82 kilohms, 5%, 2 watt
R_4 through R_{11}: 47 kilohms, 5%, 1 watt
R_{12}, R_{13}: 10 to 50 ohms, 10%, 1/2 watt

(See *Damping resistors* under *Operating Considerations, Operating Voltages*)

INTEGRAL VOLTAGE-DIVIDER NETWORK OF TYPE 8645



C_1: 68 pF ± 10%, 500 volts (dc working)

C_2: 270 pF ± 10%, 500 volts (dc working)

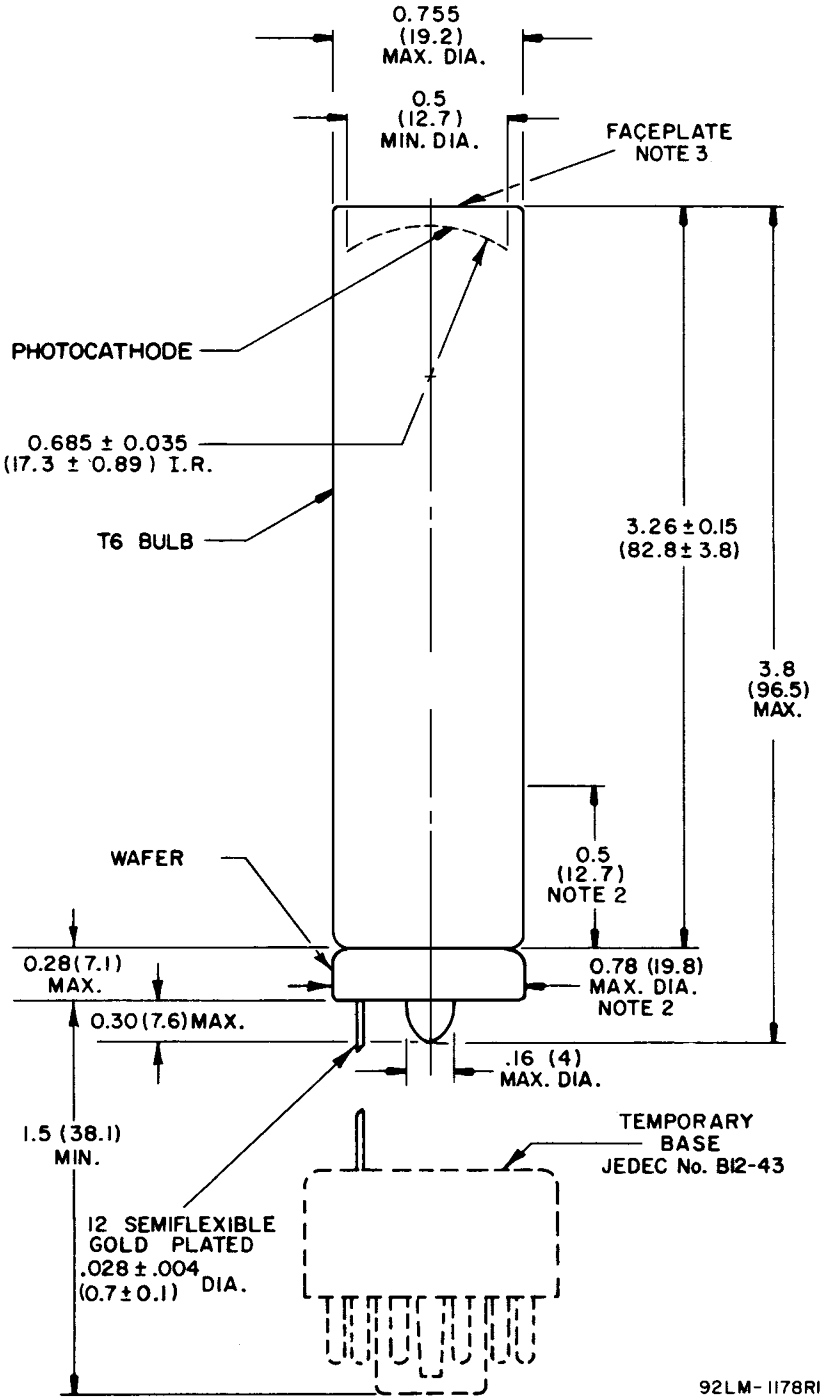
R_1: 220 kilohms, 5%, 1/4 watt

R_2: 240 kilohms, 5%, 1/4 watt

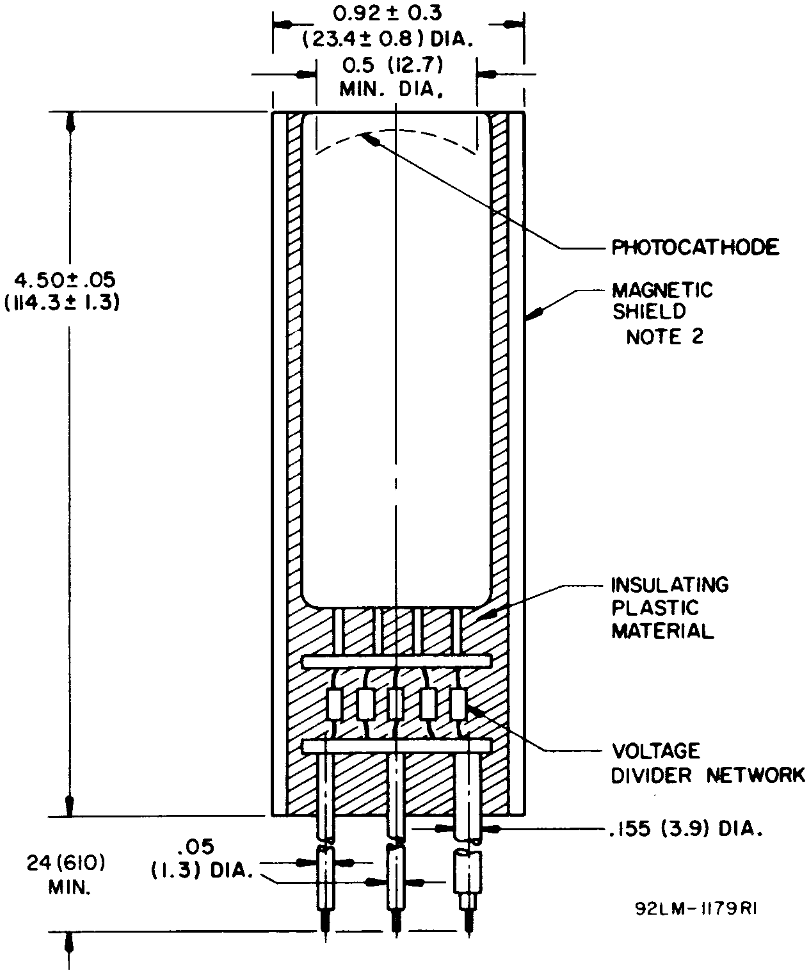
R_3: 330 kilohms, 5%, 1/4 watt

R_4 to R_{11}: 200 kilohms, 5%, 1/4 watt

DIMENSIONAL OUTLINE (TYPE 8644)

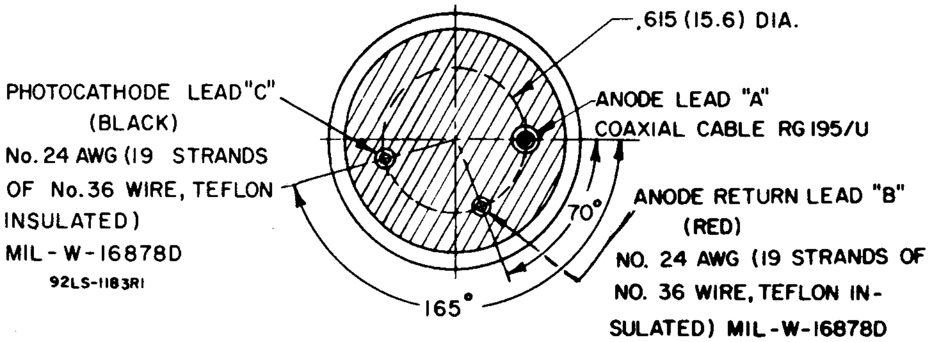


DIMENSIONAL OUTLINE (TYPE 8645)



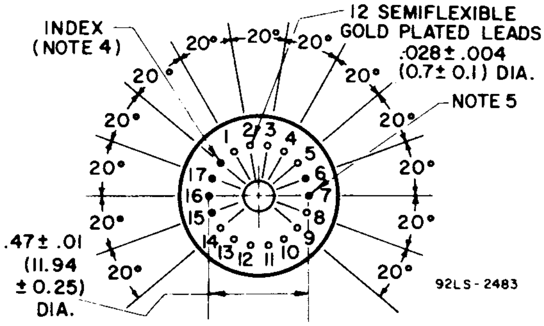
NOTE 1: Dimensions are in inches unless otherwise stated. Dimensions in parentheses are in millimeters.

NOTE 2: Wall thickness of magnetic shield is 0.020" (0.5 mm) Netic* and 0.014" (0.355) Conetic*.



* Made by Magnetic Shield Division, Perfection Mica Company, 1322 North Elston, Chicago 24, Illinois, or equivalent material.

LEAD ORIENTATION (Bottom View)



NOTE 1: Dimensions are in inches unless otherwise stated. Dimensions in parentheses are in millimeters.

NOTE 2: Within this length, maximum diameter of tube is 0.78 inch (19.8 mm).

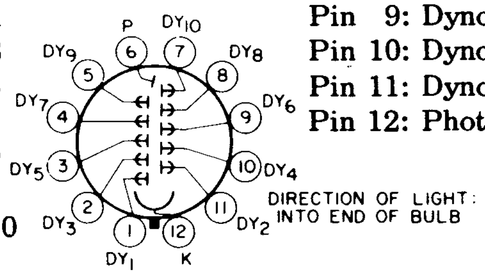
NOTE 3: Deviation from flatness within a concentric circle, 0.55 inch (14 mm) diameter will not exceed 0.006 inches (0.15 mm) peak to valley.

NOTE 4: Lead is cut off within 0.06 inch (1.5 mm) of glass button for indexing.

NOTE 5: Leads 6, 7, 15, 16, and 17 are cut off within 0.06 inch (1.5 mm) of glass button.

TERMINAL DIAGRAM With Temporary Base, JEDEC B12-43, Bottom View

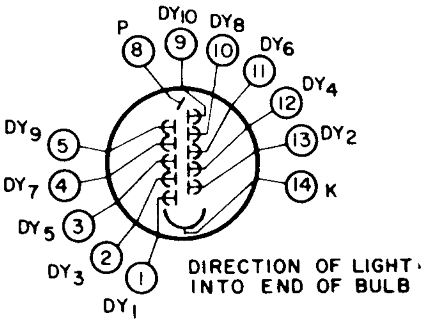
Pin 1: Dynode No.1
Pin 2: Dynode No.3
Pin 3: Dynode No.5
Pin 4: Dynode No.7
Pin 5: Dynode No.9
Pin 6: Anode
Pin 7: Dynode No.10
Pin 8: Dynode No.8



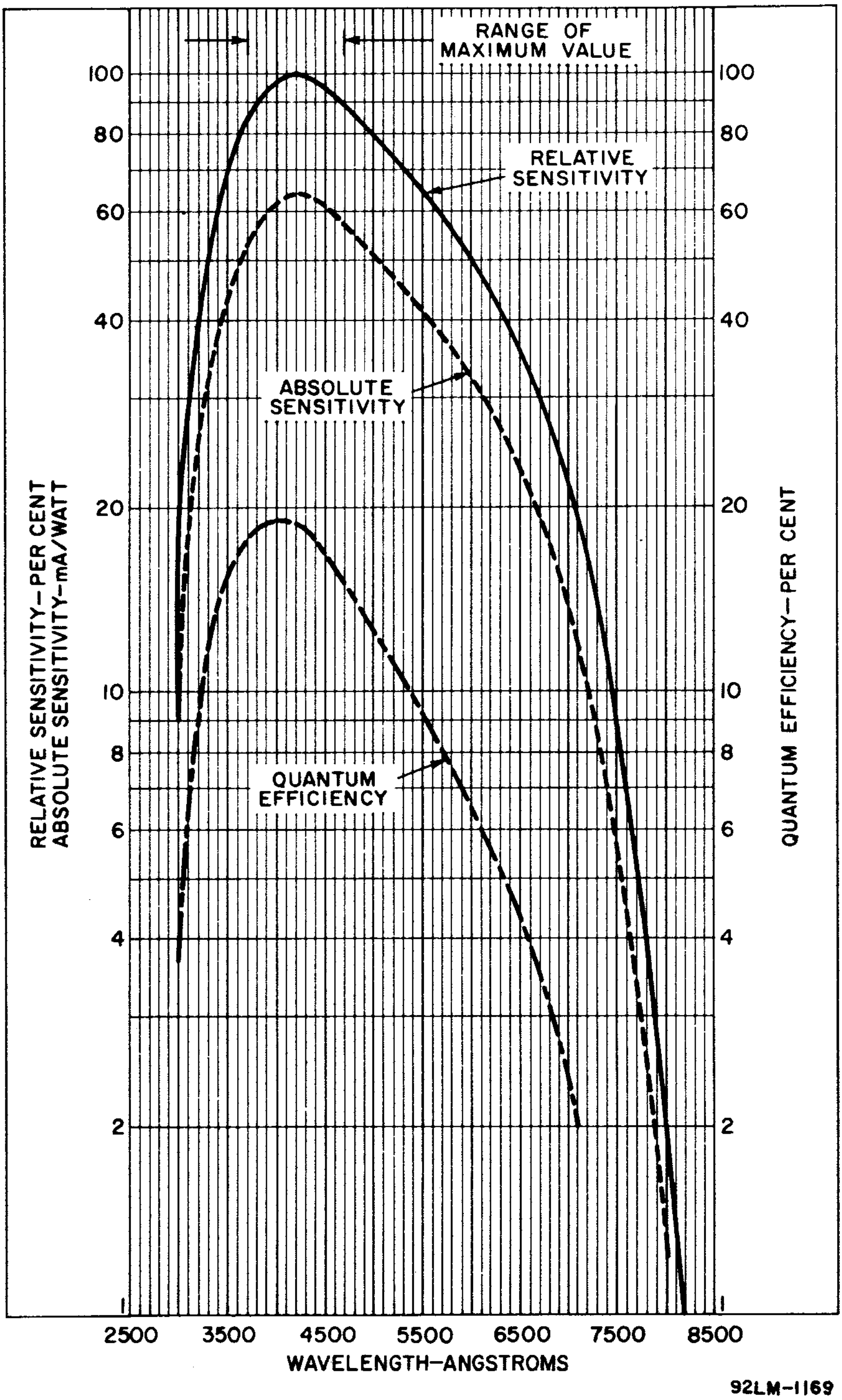
Pin 9: Dynode No.6
Pin 10: Dynode No.4
Pin 11: Dynode No.2
Pin 12: Photocathode

LEAD TERMINAL CONNECTIONS (Bottom View)

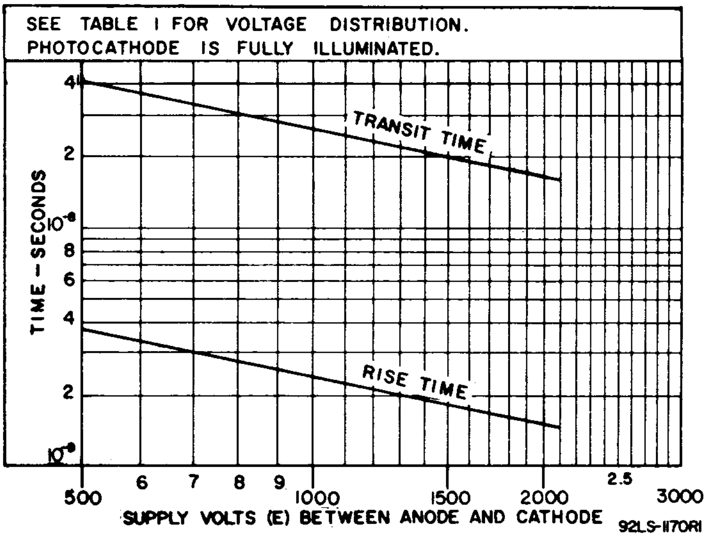
Lead 1: Dynode No.1
Lead 2: Dynode No.3
Lead 3: Dynode No.5
Lead 4: Dynode No.7
Lead 5: Dynode No.9
Lead 8: Anode
Lead 9: Dynode No.10
Lead 10: Dynode No.8
Lead 11: Dynode No.6
Lead 12: Dynode No.4
Lead 13: Dynode No.2
Lead 14: Photocathode



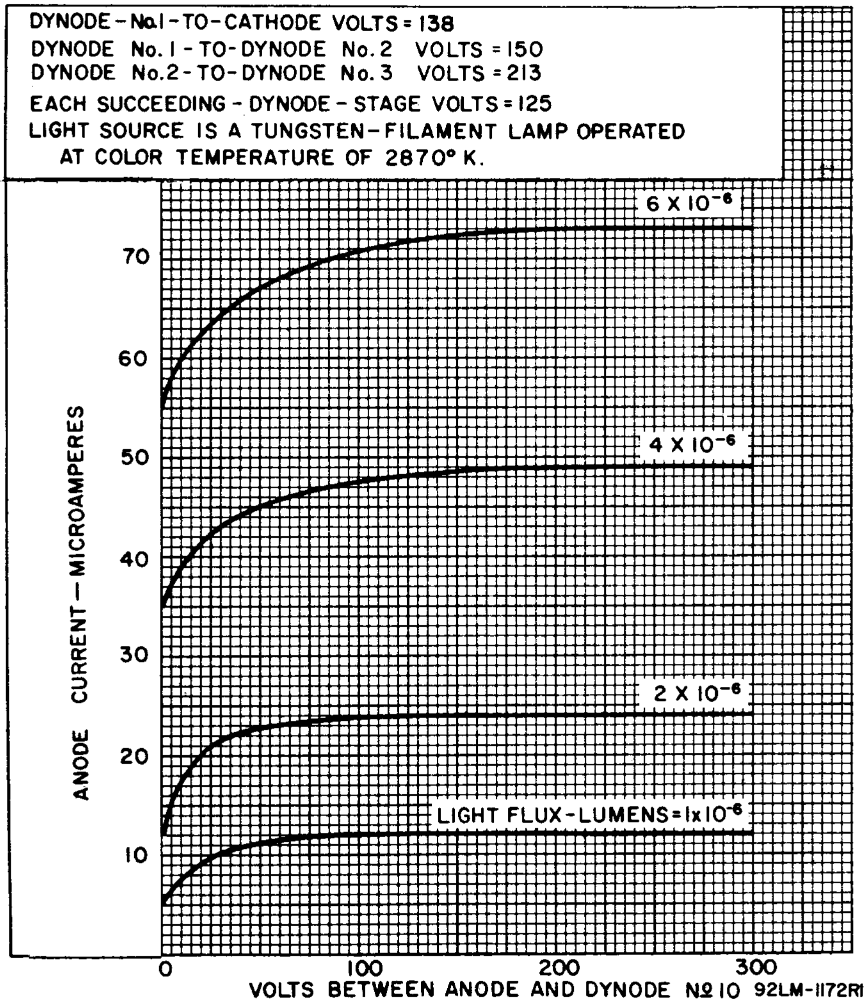
SPECTRAL RESPONSE CHARACTERISTICS



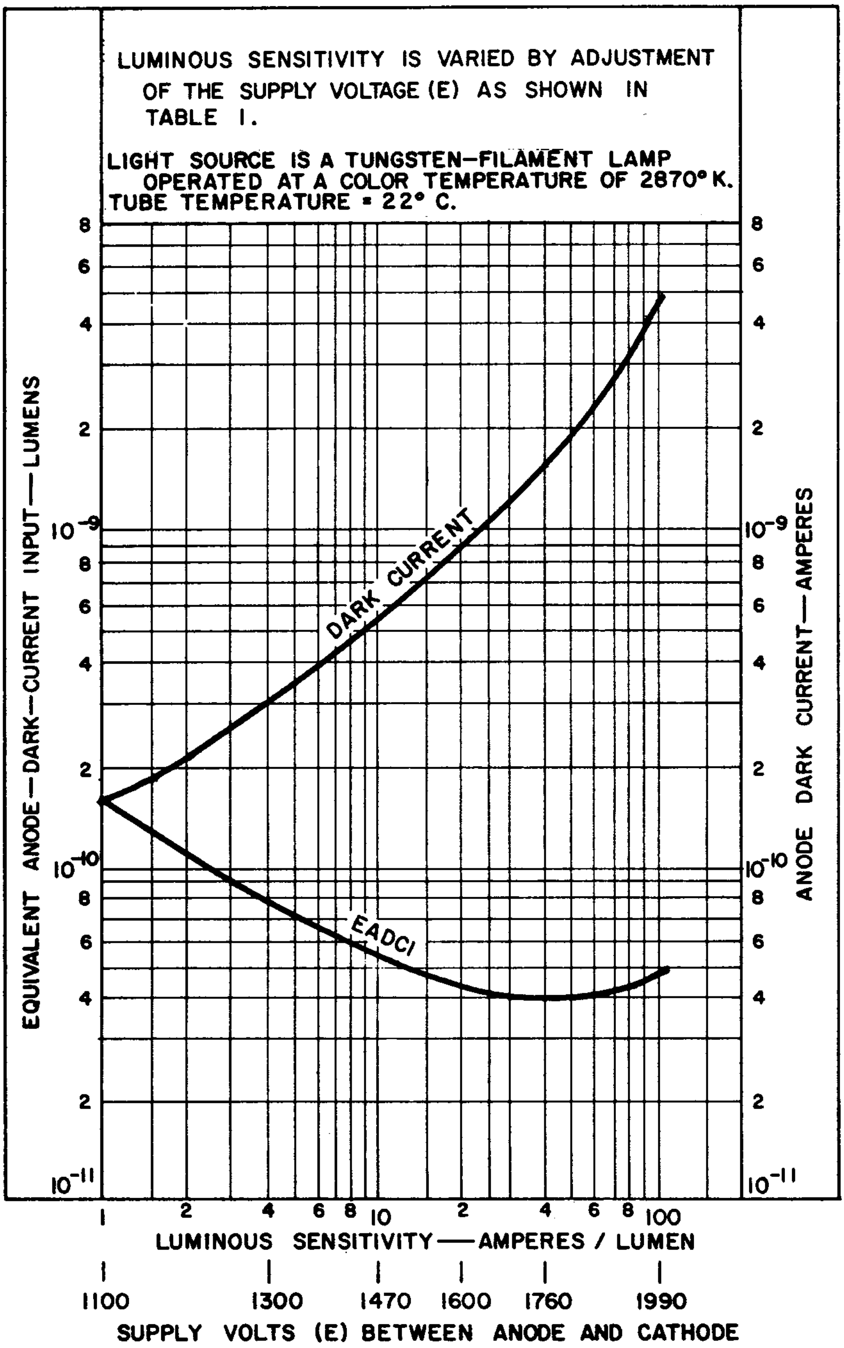
TYPICAL TIME-RESOLUTION CHARACTERISTICS



AVERAGE ANODE CHARACTERISTICS FOR TYPE 8644



TYPICAL DARK CURRENT AND EADCI CHARACTERISTICS



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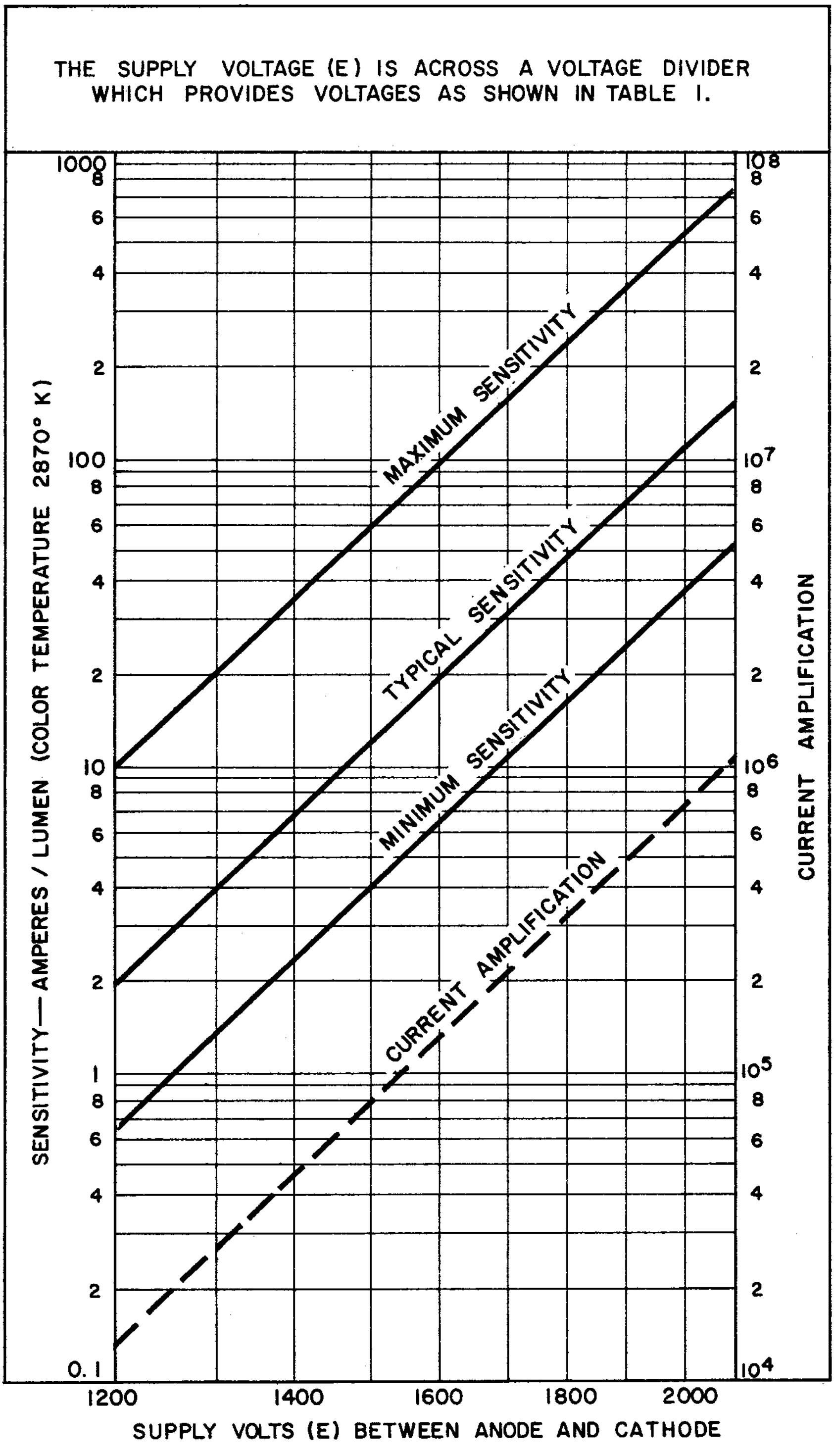
TYPICAL SENSITIVITY AND CURRENT AMPLIFICATION CHARACTERISTICS



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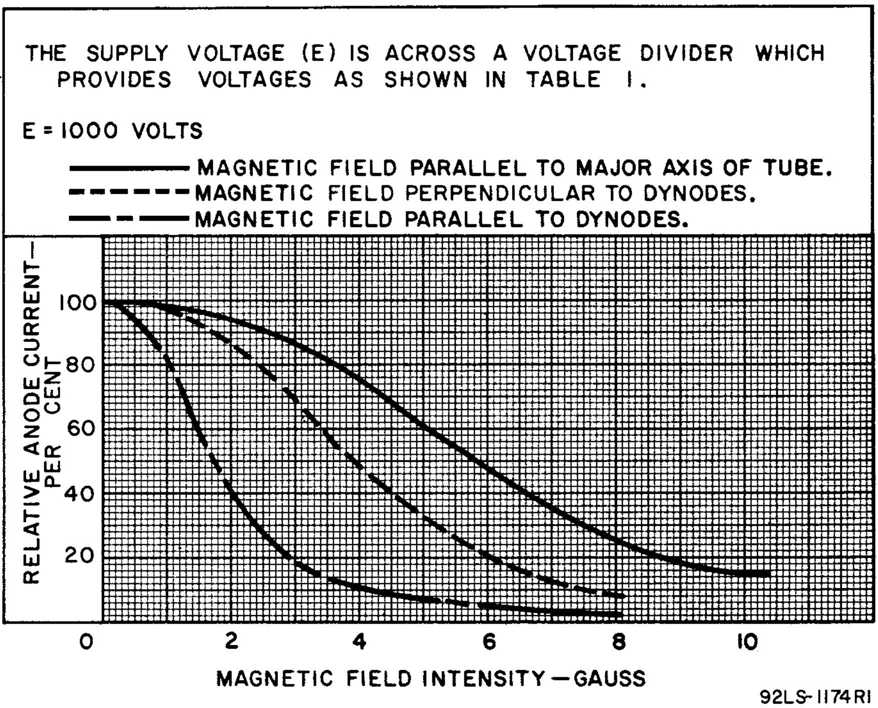
TYPICAL EFFECT OF MAGNETIC FIELD ON ANODE CURRENT FOR TYPE 8644



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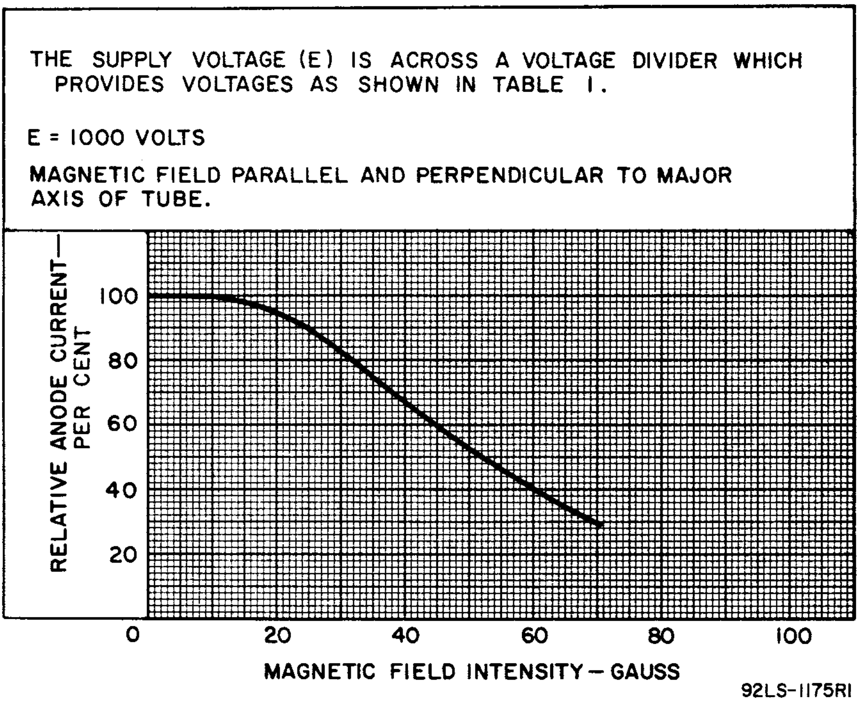
TYPICAL EFFECT OF MAGNETIC FIELD ON ANODE CURRENT FOR TYPE 8645



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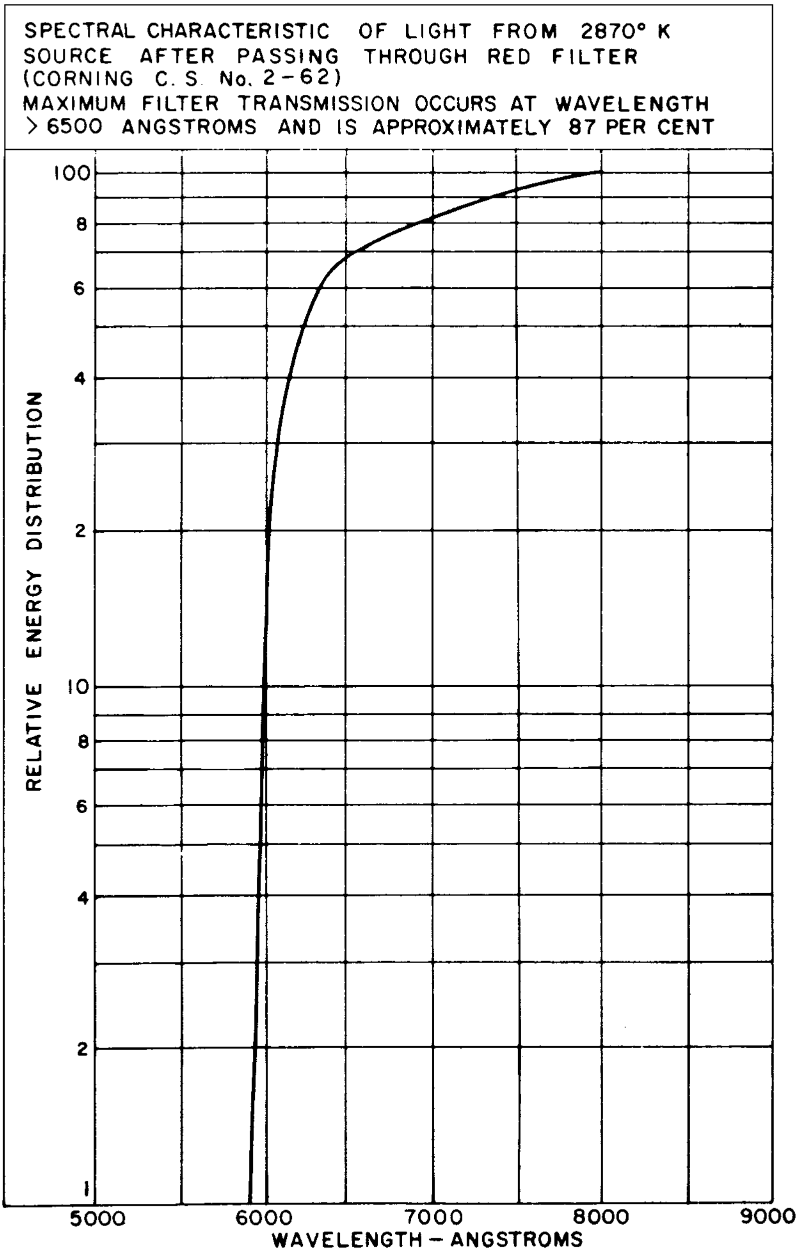
→ Indicates a change

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



For *Spectral Energy Distribution* of 2870° K Light Source after passing through *Blue* Filter, see front of this section.