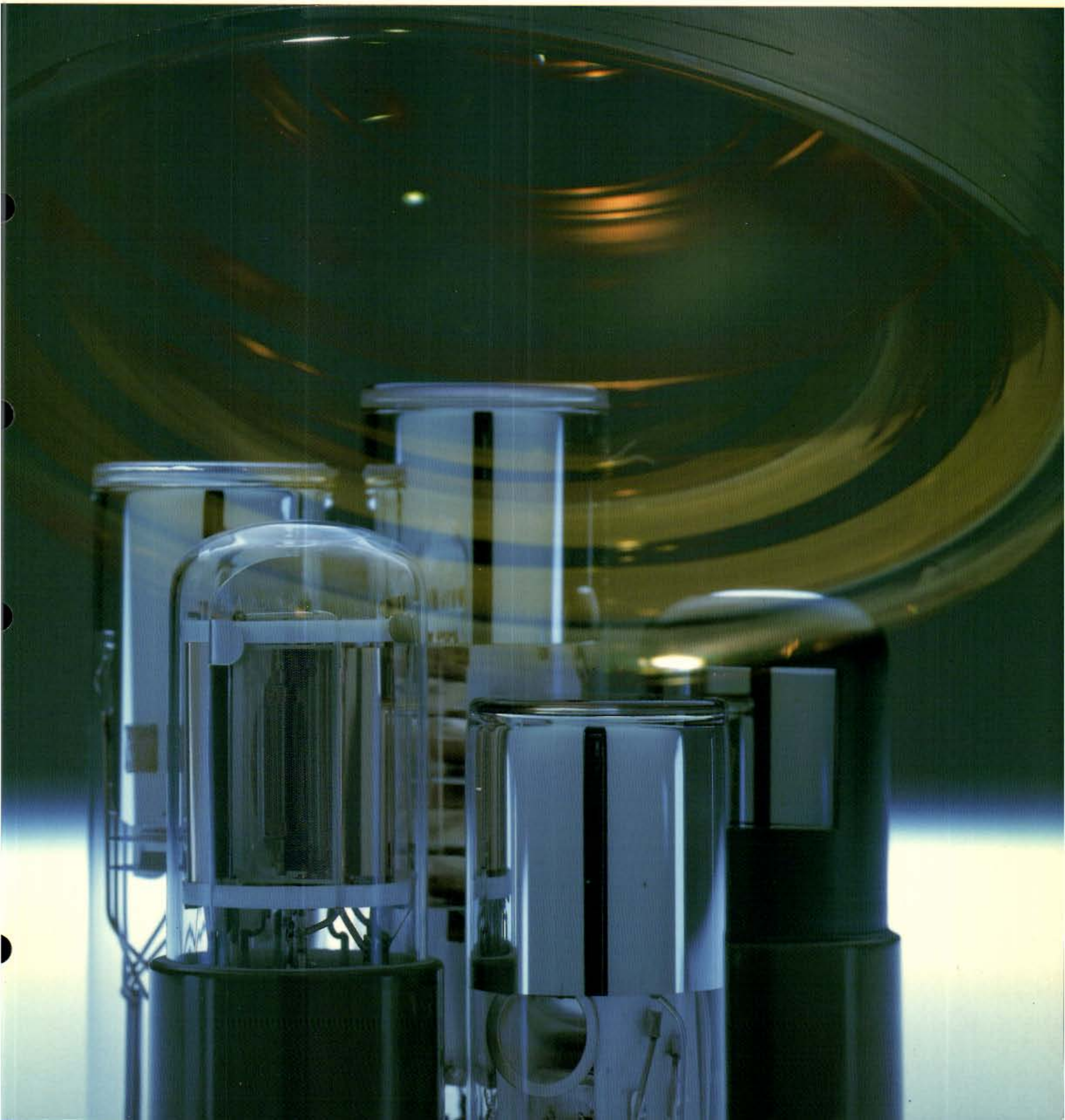
HAMAMATSU

Photomultiplier Tubes



Opening The Future with Photonics

Hamamatsu has been engaged in photonics technology for more than 30 years and has developed a variety of photonic devices such as photodetectors, imaging devices, and scientific light sources. Our state-of-the-art photonic devices have applications in a wide range of fields, including scientific research, medical and industrial instrumentation, and physical photometry as well as general electronics. The continually expanding frontiers of science demand equally constant exploration of new technology. Hamamatsu's research and development of photonic devices not only keep pace with scientific needs, but stay one step ahead, pioneering new trails into the future of light and optics.

This catalog provides information on our photomultiplier tubes, their accessories, electron multipliers and microchannel plates. But this catalog is just the starting point of our line because we will modify our production specs or design completely new types to match your performance specs.

Variants of the listed types are usually available with:
1. Different photocathode materials
2. Different window materials
3. Different configurations and pin connections
4. Other special requirements for your applications

For further information, please contact your nearest Hamamatsu sales offices.

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PHOTOMULTIPLIER TUBES

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INTRODUCTION

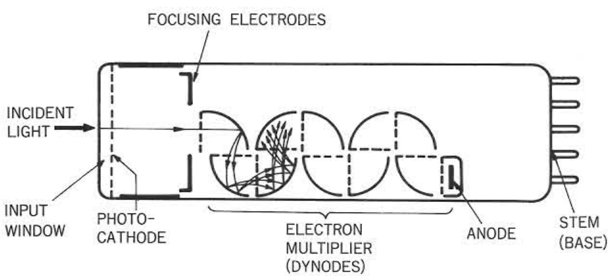
The photomultiplier tube (or PMT) is a photosensitive device consisting of a photoemissive cathode (photocathode) followed by focusing electrodes, an electron multiplier and an electron collector (anode) in a vacuum tube, as shown in Figure 1.

When light enters the photocathode, the photocathode emits photoelectrons into the vacuum. These photoelectrons are then directed by the focusing electrode voltages towards the electron multiplier where electrons are multiplied by the process of secondary emission. The multiplied electrons are collected by the anode as an output signal.

Because of secondary-emission multiplication, photomultiplier tubes are uniquely sensitive among photosensitive devices currently used to detect radiant energy in the ultraviolet, visible, and near infrared regions. The photomultiplier tube also features fast time response and low noise.

This section describes the prime features of photomultiplier tube construction and basic operating characteristics.

Figure 1: Cross-Section of Head-On Type PMT



CONSTRUCTION

The photomultiplier tube generally has a photocathode in either a side-on or a head-on configuration. The side-on type receives incident light through the side of the glass bulb, while, in the head-on type, it is received through the end of the glass bulb. In general, the side-on type photomultiplier tube is relatively low priced and widely used for spectrophotometers and general photometric systems. Most of the side-on types employ an opaque photocathode (reflection-mode photocathode) and a circular-cage structure electron multiplier which has good sensitivity and high amplification at a relatively low supply voltage.

The head-on type (or the end-on type) has a semitransparent photocathode (transmission-mode photocathode) deposited upon the inner surface of the entrance window. The head-on type provides better uniformity than the side-on type having a reflection-mode photocathode. Other features of head-on types include a choice of photosensitive area from tens of square milimeters to hundreds of square centimeters.

Variants of the head-on type having a hemispherical window have been developed for high energy physics experiments where a large diameter and good angular light acceptability are important.

Figure 2: External Appearance

a) Side-On Type **b) Head-On Type**

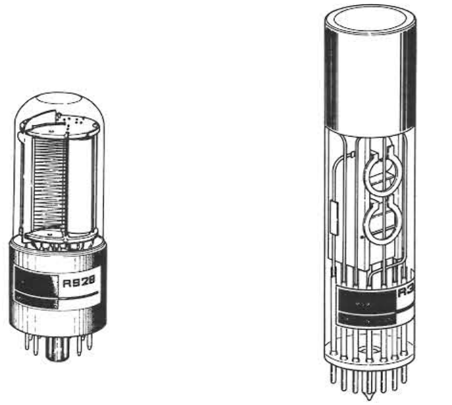
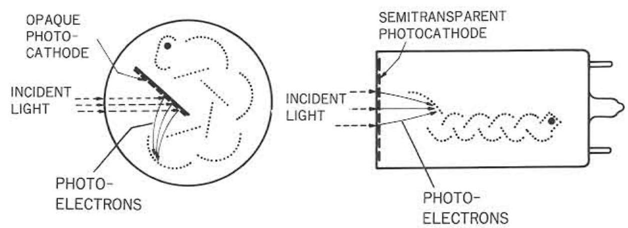


Figure 3: Types of Photocathode

a) Reflection Mode **b) Transmission Mode**



ELECTRON MULTIPLIER

The superior sensitivity (high gain and high S/N ratio) of photomultiplier tubes is due to the use of a low-noise electron multiplier which amplifies electrons by a cascade secondary emission process. The electron multiplier consists of from several up to 15 stages of electrodes called dynodes.

There are several principal types in use today.

1) Circular-cage type

The circular cage is generally used for the side-on type of photomultiplier tube. The prime features of the circular-cage are its compactness and fast response.

2) Box-and-grid type

This type consists of a train of quarter cylindrical dynodes and is widely used in head-on type photomultiplier tubes because of its relatively easy dynode design and better uniformity, although time response may be a problem in some applications.

3) Liner focused type

Since this type features fast response time, it is widely used in applications where time resolution and pulse linearity are important.

4) Venetian blind type

The venetian blind type has a large dynode area and is primarily used for tubes with large photocathode areas. It offers better uniformity and a larger output current. This structure is usually used when time response is not a prime consideration.

5) Proximity mesh type

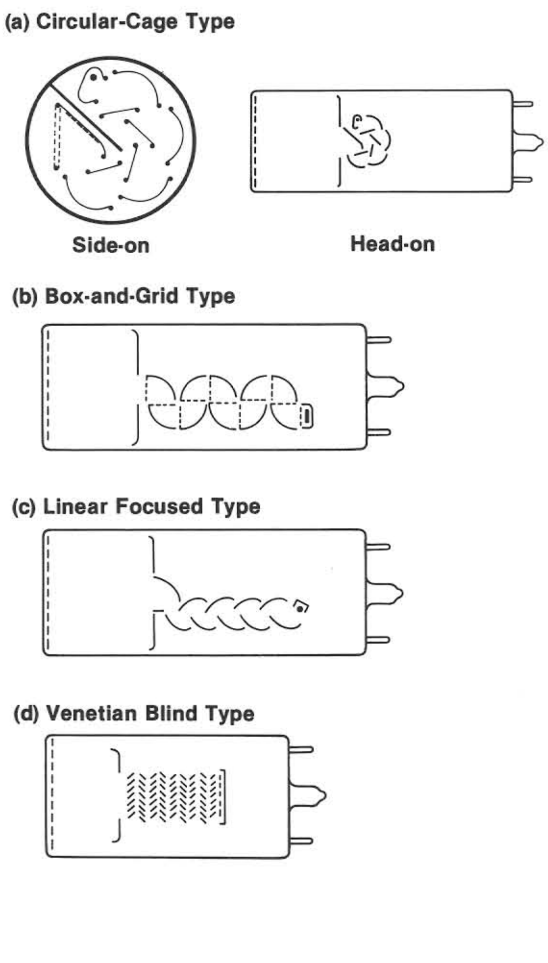
In addition to good uniformity and high pulse linearity, this type provides high immunity to magnetic fields. Also, it has position-sensitive capability when used with multiple anodes.

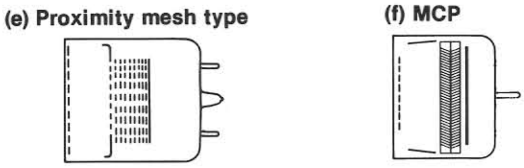
6) Microchannel plate (MCP)

The MCP has much faster time response than the other discrete dynodes. It also features good immunity magnetic fields and two-dimensional detection ability when multiple anodes are used.

Recently hybrid dynodes combining two of the above dynodes have been developed. These hybrid dynodes are desi gned to provide the merits of each dynode.

Figure 4: Types of Electron Multipliers



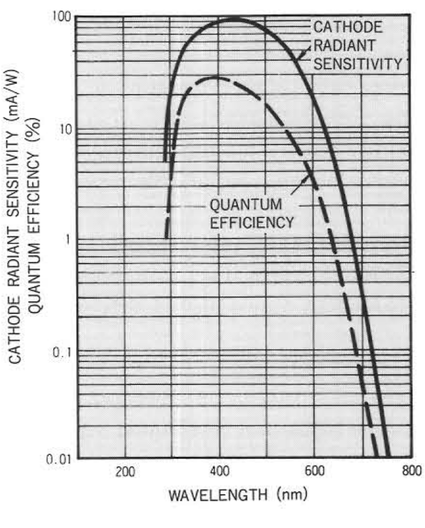


SPECTRAL RESPONSE

The photocathode of photomultiplier tubes converts energy of incident light into electrons. The conversion efficiency (photocathode sensitivity) varies with the wavelength of incident light. This relationship between photocathode sensitivity and wavelength is called the spectral response characteristic. Figure 5 shows a typical spectral response of the bialkali photomultiplier tube. The spectral response range is determined on the long wavelength side by the photocathode material and on the short wavelength side by the window material. Typical spectral response characteristics for various types of photomultiplier tubes are shown on the inside back cover.

In this catalog, the long-wavelength cutoff of spectral response characteristics is defined as the wavelength at which the cathode radiant sensitivity becomes 1% of the maximum sensitivity for bialkali and Ag-O-Cs photocathodes, and 0.1% of the maximum sensitivity for multialkali photocathodes. Spectral response characteristics shown inside the back cover are typical curves for representative tube types. Typical radiant sensitivity for individual tube types is listed in their characteristic tables. But actual data may be different from tube to tube.

Figure 5: Typical Spectral Response of Bialkali Photocathode (R878, etc.)



Photocathode Materials

The photocathode is a photoemissive surface usually consisting of alkali metals with very low work functions. The photocathode materials most commonly used in photomultiplier tubes are as follows:

1) Ag-O-Cs

The transmission-mode photocathode using this material is designated S-1. It is sensitive from the visible to infrared radiation beyond 1000 nm. Since it has high adverse dark emission, tubes of this photocathode are chiefly used for detection in the infrared region with the photocathode cooled.

2) Sb-Cs

This is a widely used photocathode and has a spectral response in the ultraviolet to visible range. Mainly used for reflection-mode photocathodes.

3) Bialkali (Sb-Rb-Cs, Sb-K-Cs)

These have a spectral response range similar to the Sb-Cs photocathode, but have higher sensitivity and lower noise than Sb-Cs. They also have a favorable blue sensitivity for scintillator flashes, thus they are frequently used for scintillation counting.

4) High temperature bialkali, low noise bialkali (Na_2-K-Sb)

This is particularly useful at higher operating temperatures since it can withstand up to 175°C. A major application is in the oil well logging industry. At room temperatures, it operates with very low dark current. Thus it can also be useful for photon counting applications.

5) Multialkali (Na-K-Sb-Cs)

The multialkali photocathode has a high, wide spectral response from the ultraviolet to near infrared region. It is widely used for broad-band spectrophotometers and photon counting applications. The long wavelength response can be extended out to 930 nm by special photocathode processing.

6) GaAs (Cs)

GaAs activated in cesium is also used as a photocathode. The spectral response of this photocathode usually covers a wider range than multialkali, ultraviolet to 930 nm, and is very flat.

7) InGaAs

This new photocathode has more extended sensitivity in infrared than GaAs. Also, in the range between 900 and 1000 nm, InGaAs has much higher S/N ratio than Ag-O-Cs.

8) Cs-Te, Cs-I

These materials are sensitive to vacuum UV and UV rays but not to visible light and are therefore called solar blind. Cs-Te is quite insensitive to wavelengths longer than 320 nm and Cs-I to those longer than 200 nm.

Window Materials

The window materials commonly used in photomultiplier tubes are as follows:

1) Borosilicate glass

This is the most frequently used material. It transmits radiation from the infrared to approximately 300 nm. It is not suitable for detection in the ultraviolet region.

For scintillation counting applications, the low-noise borosilicate glass (so called K free glass) may be used. It contains very low potassium (^{40}K) which can cause unwanted background counts.

2) UV-transmitting glass (UV glass)

This glass transmits ultraviolet radiation well, as the name implies, and is used as widely as borosilicate glass. The UV cutoff is approximately 185 nm.

3) Synthetic silica

This material transmits ultraviolet radiation down to 160 nm. Since silica has a different thermal expansion coefficient from Kovar, which is used for the tube leads, it is not suitable for the stem material of the tube. Borosilicate glass is used for the stem, then a graded seal using glasses with gradually different thermal expansion coefficient are connected to the fused silica window.

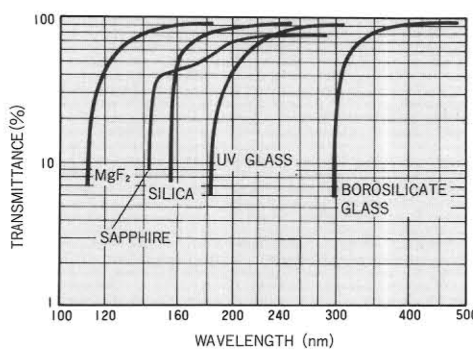
4) Sapphire glass

The sapphire glass made of Al_2O_3 crystal has an intermediate transmittance in the ultraviolet region between UV glass and synthetic silica. But, at wavelengths shorter than 150 nm, it has higher transmittance than synthetic silica. Since the sapphire glass does not require graded seal, the overall length of tubes can be shortened.

5) MgF_2 (magnesium fluoride)

The crystals of alkali halide are superior in transmitting ultraviolet radiation, but deliquescence is a common problem. Among them, MgF_2 has low deliquescence and transmits ultraviolet radiation down to 115 nm.

Figure 6: Typical Transmittance of Various Window Materials



As stated above, spectral response range is determined by the photocathode and window materials. It is important to select an appropriate combination which will suit your applications.

RADIANT SENSITIVITY AND QUANTUM EFFICIENCY

As Figure 5 shows, spectral response is usually expressed in terms of radiant sensitivity and quantum efficiency.

Radiant sensitivity is the photoelectric current from the photocathode divided by the incident radiant power at a given wavelength, expressed in A/W (amperes per watt).

Quantum efficiency (QE) is defined as the ratio of the number of incident photons to resulting photoelectrons emitted from the photocathode. It is customary to present quantum efficiency as a percent. Quantum efficiency and radiant sensitivity have the following relationship at a given wavelength.

$$QE = \frac{S \times 1240}{\lambda} \times 100\ (\%)$$

where S is the radiant sensitivity in A/W at the given wavelength and λ is the wavelength in nm (nanometers).

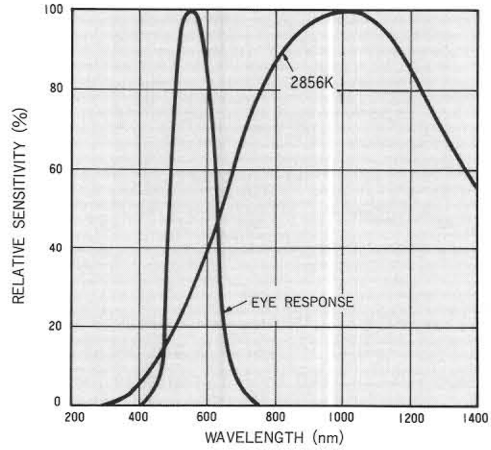
LUMINOUS SENSITIVITY

Since the measurement of spectral response characteristic of a photomultiplier tube requires a sophisticated system and time, it is not practical to provide customers with spectral response characteristics of each tube ordered. Instead, a value of cathode or anode luminous sensitivity is commonly used.

The cathode luminous sensitivity is the photoelectric current from the photocathode per incident light flux (10^{-5} to 10^{-2} lumen) from a tungsten filament lamp operated at a distribution temperature of 2856K. The anode luminous sensitivity is the anode output current (amplified by the secondary emission process) per incident light flux (10^{-10} to 10^{-5} lumen) on the photocathode. Although the same tungsten lamp is used, the light flux and the applied voltage are adjusted to an appropriate level. These parameters are particularly useful when comparing tubes having the same or similar spectral response range. Hamamatsu final test sheets accompanying the tubes usually indicate these parameters except for tubes with CsI or CsTe photocathodes which are not sensitive to tungsten lamp light. (Radiant sensitivity at a specific wavelength is listed for those tubes instead.)

Both the cathode and anode luminous sensitivities are expressed in units of A/lm (amperes per lumen). Note that the lumen is a unit used for luminous flux in the visible region and therefore these values may be meaningless for tubes which are sensitive beyond the visible region. For those tubes, the blue sensitivity or red/white ratio is often used.

Figure 7: Typical Human Eye Response and Spectral Distribution of 2856K Tungsten Lamp



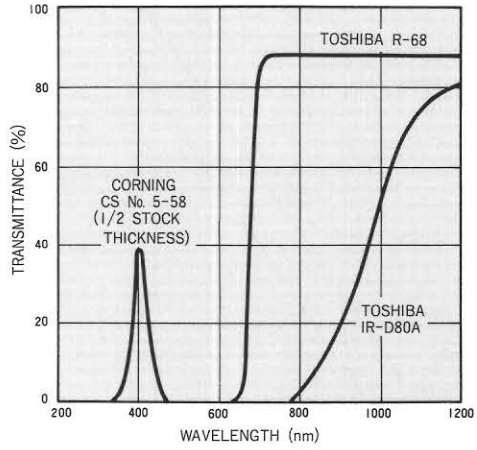
BLUE SENSITIVITY AND RED/WHITE RATIO

For simple comparison of spectral response of photomultiplier tubes, cathode blue sensitivity and red/white ratio are often used.

The cathode blue sensitivity is the photoelectric current from the photocathode produced by a light flux of a tungsten lamp at 2856K passing through a blue filter (Corning CS No. 5-58 polished to half stock thickness). Since the light flux, once transmitted through the blue filter cannot be expressed in lumens, blue sensitivity is usually presented in A/lm-b (amperes per lumen-blue). The blue sensitivity is a very important parameter in scintillation counting since scintillators produce emissions in the blue region of the spectrum, and may dominate energy resolution.

The red/white ratio is used for photomultiplier tubes with a spectral response extending to the near infrared region. This parameter is defined as the quo-

Figure 8: Transmittance of Filters



tient of the cathode sensitivity measured with a light flux of a tungsten lamp at 2856K passing through a red filter (Toshiba IR-D80A for the S-1 photocathode or R-68 for others) divided by the cathode luminous sensitivity with the filter removed.

CURRENT AMPLIFICATION (GAIN)

Photoelectrons emitted from a photocathode are accelerated by an electric field so as to strike the first dynode and produce secondary electron emissions. These secondary electrons then impinge upon the next dynode to produce additional secondary electron emissions. Repeating this process over successive dynode stages, a high current amplification is achieved. A very small photoelectric current from the photocathode can be observed as a large output current from the anode of the photomultiplier tube.

Current amplification is simply the ratio of the anode output current to the photoelectric current from the photocathode. Ideally, the current amplification of a photomultiplier tube having n dynode stage and an average secondary emission ratio δ per stage is δ^n. While the secondary electron emission ratio δ is given by

$$\delta = A \cdot E^{\alpha}$$

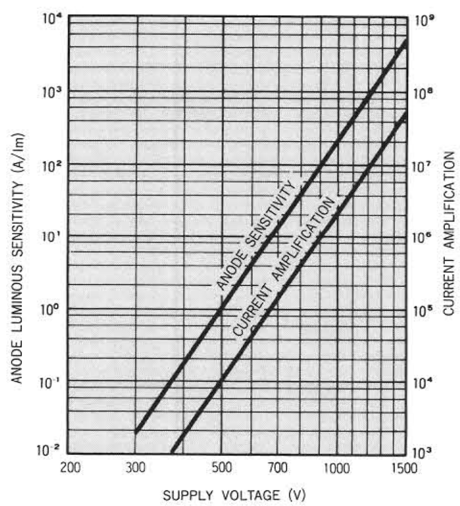
where A is constant, E is interstage voltage, and α is a coefficient determined by the dynode material and geometric structure. It usually has a value of 0.7 to 0.8.

When a voltage V is applied between the cathode and the anode of a photomultiplier tube having n dynode stages, current amplification, G, becomes

$$G = \delta^n = (A \cdot E^{\alpha})^n = \left\{A\left(\frac{V}{n+1}\right)^{\alpha}\right\}^n$$

$$= \frac{A^n}{(n+1)^{\alpha n}} \cdot V^{\alpha n} = K \cdot V^{\alpha n} \quad \text{(K: constant)}$$

Figure 9: Typical Current Amplification vs. Supply Voltage



Since generally photomultiplier tubes have 9 to 12 dynode stages, the anode output varies directly with the 6th to 10th power of the change in applied voltage. The output signal of the photomultiplier tube is extremely susceptible to fluctuations in the power supply voltage, thus the power supply should be very stable and exhibit minimum ripple, drift and temperature coefficient. Regulated high voltage power supplies designed with this consideration are available from Hamamatsu (see page 69).

ANODE DARK CURRENT

A small amount of current flows in a photomultiplier tube even when the tube is operated in complete darkness. This output current, called the anode dark current, and the resulting noise are critical factors in determining the lower limit of light detection. Figure 10 shows that dark current is greatly dependent on the supply voltage.

Other sources of dark current may be categorized as follows:

1) Thermionic emission of electrons

Since the materials of the photocathode and dynodes have very low work functions, they emit thermionic electrons even at room temperature. Most of dark currents originate from the thermionic emissions, especially from the photocathode and, if so, become multiplied by the dynodes. Cooling the tube is most useful in applications where low dark current is essential such as in photon counting.

Figure 10: Typical Dark Current vs. Supply Voltage

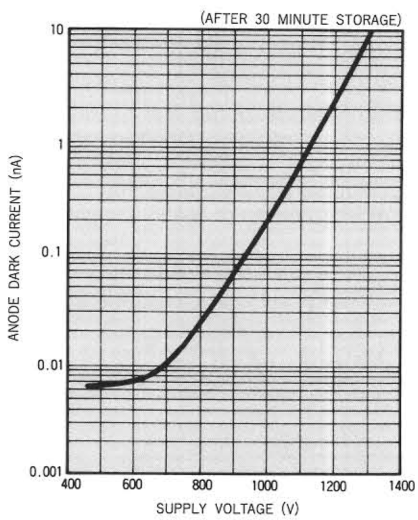
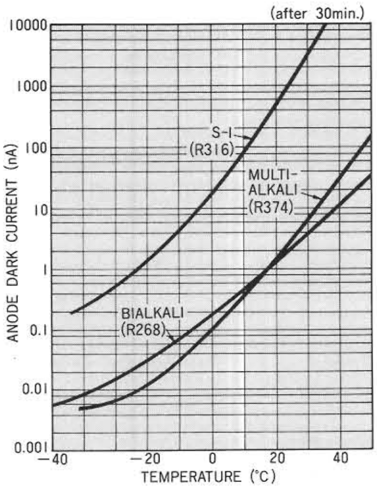


Figure 11 shows the relationship between dark current and temperature for various photocathodes. Photocathodes which have high sensitivity in the red to infrared region, especially S-1, show higher dark current at room temperature.

Figure 11: Temperature Characteristics of Dark Current



Hamamatsu provides thermoelectric coolers designed for various sizes of photomultiplier tubes (see page 68).

2) Ionization of residual gases

Residual gases inside a photomultiplier tube can be ionized by the flow of photoelectrons. When these ions strike the photocathode or earlier stages of dynodes, secondary electrons may be emitted, thus resulting in relatively large output noise pulse. These noise pulses are usually observed as afterpulses following the primary signal pulses and may be a problem in detecting short light pulses. Present photomultiplier tubes are designed to minimize afterpulses.

3) Glass scintillation

When electrons deviating from their normal trajectories strike the glass envelope, scintillations may occur and a dark pulse may result. To eliminate this type of dark pulse, photomultiplier tubes may be operated with the anode at high voltage and the cathode at ground potential. Here it is useful to coat the glass bulb with a conductive paint (HA Coating) connected to the cathode (see page 13).

4) Ohmic leakage

Ohmic leakage resulting from imperfect insulation of the glass stem base and socket may be another source of dark current. This is predominant when the photomultiplier tube is operated at a low voltage or low temperature. The flatter slopes in Figure 10 and 11 are mainly due to ohmic leakage.

Contamination consisting of dirt and humidity on the surface of the tube may contribute to ohmic leakage, and therefore should be avoided.

5) Field emission

When a photomultiplier tube is operated at a voltage near the maximum rating value, electrons may be emitted from electrodes by the strong electric field and may cause dark pulses. It is therefore recommended that the tube be operated at 200 to 300 volts lower than the maximum rating.

The anode dark current decreases with time after the tube is placed in darkness. In this catalog, anode dark currents are measured after 30 minutes storage in darkness.

ENI (EQUIVALENT NOISE INPUT)

ENI is an indication of the photon-limited signal-to-noise ratio. It refers to the amount of light in watts necessary to produce a signal-to-noise ratio of unity in the output of a photomultiplier tube. The value of ENI is given by:

$$ENI = \frac{\sqrt{2q \cdot Idb \cdot G \cdot \Delta f}}{S} \quad \text{(watts)}$$

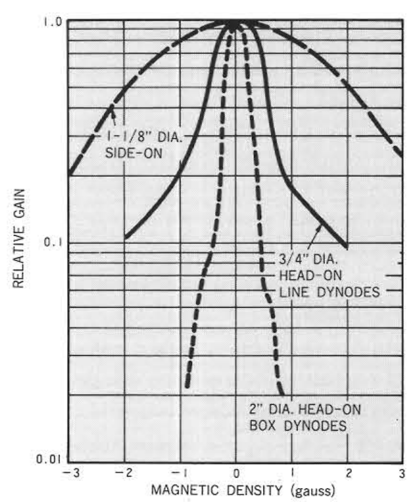
where q = electronic charge (1.60×10^{-19} coul.)
Idb = anode dark current in amperes after 15-hour storage in darkness
G = current amplification
Δf = bandwidth of the system in hertz (usually 1 hertz)
S = anode radiant sensitivity in amperes per watt at the wavelength of interest

For the tubes listed in this catalog, the value of ENI may be calculated by the above equation. Usually it has a value between 10^{-15} and 10^{-16} watts.

EFFECT BY MAGNETIC FIELD

Most photomultiplier tubes are affected by the presence of magnetic fields. Magnetic fields may deflect electrons from their normal trajectories and cause a loss of gain. The extent of the loss of gain depends on the type of photomultiplier tube and its orientation in the magnetic field. Figure 12 shows

Figure 12: Typical Effects by Magnetic Fields Perpendicular to Tube Axis



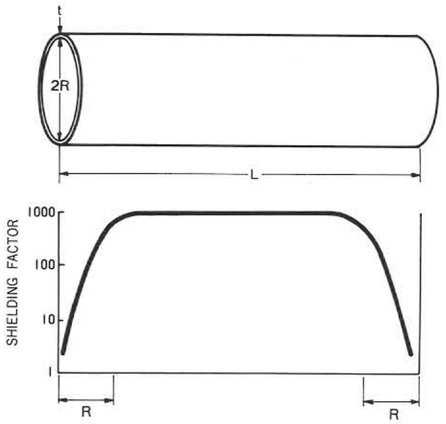
typical effects of magnetic fields on some types of photomultiplier tubes. In general, tubes having a long path from the photocathode to the first dynode are very sensitive to magnetic fields. Therefore head-on types, especially large diameter tubes, tend to be more adversely influenced by magnetic fields.

When a tube has to be operated in magnetic fields, it may be necessary to shield the tube with a magnetic shield case. (Hamamatsu provides a variety of magnetic shield cases. See page 68.) To express the effect of a magnetic shield case, the magnetic shielding factor is used, which is the ratio of the strength of the magnetic field outside the shield case, H_{out}, to that inside the shield case, H_{in}. It is determined by the permeability μ, the thickness t and inner diameter D of the shield case, as follows.

$$\frac{H_{out}}{H_{in}} \simeq \frac{3\mu t}{4D}$$

It should be noted that the magnetic shielding effect decreases towards the edge of the shield case as shown in Figure 13. It is suggested to cover the tube with a shield case longer than the tube length by at least half the tube diameter.

Figure 13: Edge Effect of Magnetic Shield Case



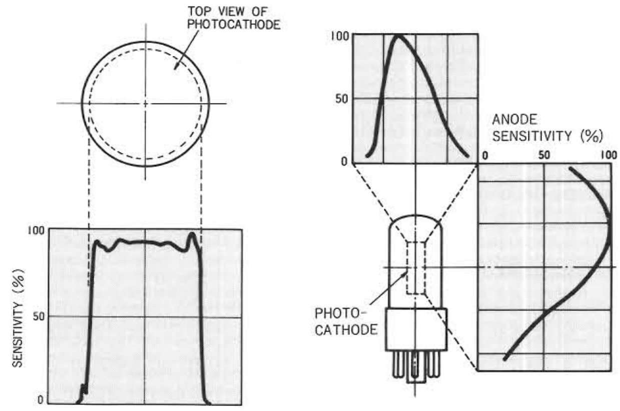
Recently proximity mesh made of non-magnetic material has been introduced as an alternate dynode in photomultiplier tubes. These tube types (see page 56) exhibit much higher immunity to external magnetic fields than the photomultiplier tubes with other dynodes. Also triode and tetrode tubes (see page 56) are useful for applications where the measured amount of light is large.

SPATIAL UNIFORMITY

Although the focusing electrodes of a photomultiplier tube are designed so that electrons emitted from the photocathode or dynodes are collected efficiently by the first or following dynodes, some electrons may deviate from their desired trajectories and collection efficiency is degraded. The collection efficiency varies with the position on the photocathode from which the photoelectrons are emitted and influences the spatial uniformity of a photomultiplier tube. The spatial uniformity is also determined by the photocathode surface uniformity itself.

In general, head-on type photomultiplier tubes provide better spatial uniformity than side-on types because of the photocathode to first dynode geometry. Tubes especially designed for gamma camera applications have excellent spatial uniformity.

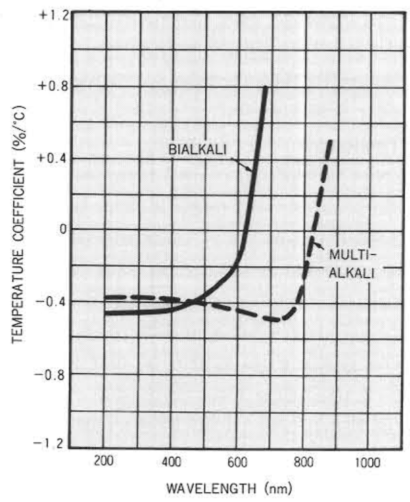
Figure 14: Examples of Spatial Uniformity
(a) Head-On Type (R1306 for γ camera) **(b) Side-On Type**



TEMPERATURE CHARACTERISTICS

As discussed earlier, by decreasing ambient temperature of a photomultiplier tube, dark current originating from thermionic emission can be reduced. Sensitivity of the photomultiplier tube also varies with the temperature. In the ultraviolet to visible region, the temperature coefficient of sensitivity has a negative

Figure 15: Typical Temperature Coefficients of Anode Sensitivity

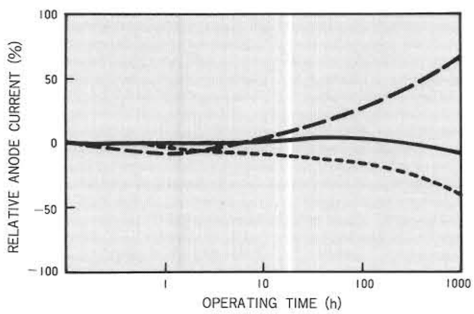


value, while near the long wavelength cutoff it has a positive value. Figure 15 shows typical temperature coefficients around room temperature for multialkali and bialkali photocathodes. Since the temperature coefficient change is large near the long wavelength cutoff, temperature control may be required in some applications.

DRIFT (ANODE CURRENT INSTABILITY)

While operating a photomultiplier tube continuously over a long period, anode output current of the photomultiplier tube may vary slightly with time, although operating conditions have not changed. This instability of anode output current is called drift. Figure 16 shows general drift curves. Drift is primarily caused by damage to the last dynode by heavy electron bombardment. The operating stability of a photomultiplier tube depends on the magnitude of the anode current and not so much on the applied voltage, and therefore the use of lower anode current is desirable. When stability is of prime importance, the use of average anode current of 1 μA or less is recommended.

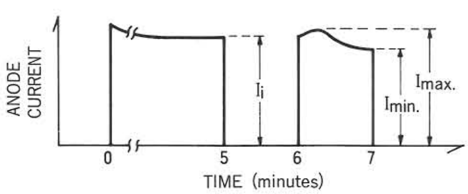
Figure 16: Examples of Drift



HYSTERESIS

Photomultiplier tubes exhibit a temporary instability in anode output current for several seconds to several tens of seconds after voltage and light are applied, i.e., sensitivity may overshoot or undershoot before reaching a stable value. This instability is called hysteresis and may be a problem in spectrophotometry and other applications.

Figure 17: Hysteresis Measurement



$$\text{HYSTERESIS} = \frac{I_{max.} - I_{min.}}{I_i} \times 100\ (\%)$$

Hysteresis is mainly caused by electrons being deviated from their planned trajectories and electrostatically charging the dynode support ceramics and glass bulb. When the applied voltage is changed as the light input changes, marked hysteresis can occur.

To eliminate hysteresis, many Hamamatsu side-on photomultiplier tubes employ "anti-hysteresis design" in which the dynode support ceramics are coated with chromium and maintained at the cathode potential in order to repulse stray electrons.

TIME RESPONSE

In application where the incident light is in the form of pulses, the anode output signal should reproduce a waveform faithful to the incident pulse waveform. This reproducibility is related to the anode pulse rise time and the electron transit time.

As illustrated in Figure 18, the anode pulse rise time is defined as the time to rise from 10% to 90% of the peak amplitude when the whole photocathode is illuminated by a delta function light pulse (pulse width less than 50 ps). The electron transit time is the time interval between the arrival of a delta function light pulse (pulse width less than 1ns) at the photocathode and the instant when the anode output pulse reaches its peak amplitude. The electron transit time has a fluctuation between individual light pulses. This fluctuation is called transit time spread (T.T.S.) and defined as the FWHM of the frequency distribution of electron transit times. The T.T.S. is an important factor in time-resolving measurement.

Those parameters are affected by the dynode structure and applied voltage. In general, tubes of the linear focused or circular cage structure exhibit better time response than tubes of the box-and-grid or venetian blind structure. Figure 19 shows typical time response characteristics vs. applied voltage for types R268 (1-1/8" dia. head-on, 11-stage, box-and-grid type) and 931A (1-1/8" dia. side-on, 9-stage, circular cage type).

Figure 18: Anode Pulse Rise Time and Electron Transit Time

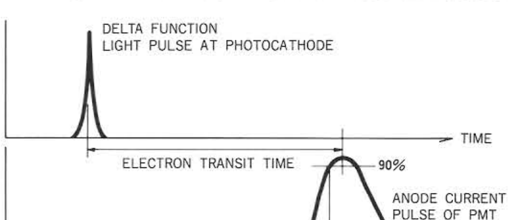


Figure 19: Transit Time Spread (T.T.S.)

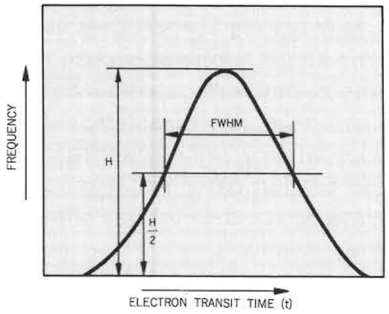
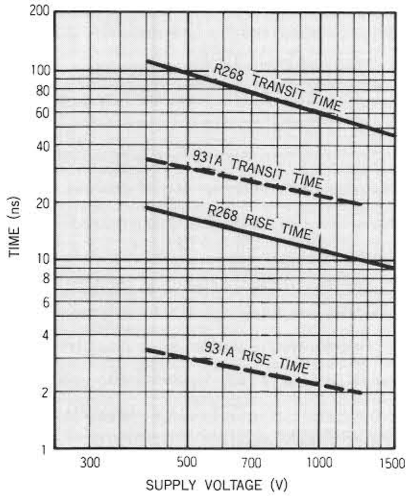


Figure 20: Time Response Characteristics vs. Supply Voltage

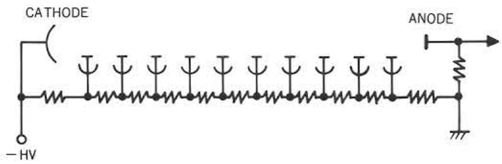


VOLTAGE-DIVIDER CONSIDERATION

Interstage voltages for the dynodes of a photomultiplier tube are usually supplied by a voltage-divider network consisting of series-connected resistors. Schematic diagrams of typical voltage-divider networks are illustrated in Figure 21. Circuit (a) is a basic arrangement and (b) is for high-current pulse operations. Figure 22 shows the response of a photomultiplier tube using the voltage-divider (a) as a function of the input light flux. Deviation from linearity (over-response, region A) is caused by an increase in dynode voltage resulting from the redistribution of the voltage loss between the last dynode and the anode. As the input light level is increased, the anode output current begins to saturate near the value of the current flowing through the voltage divider (region C) due to the extension of voltage losses to the last few stages. Therefore, the upper limit of dynamic range of the photomultiplier tube is determined by the voltage-divider current. To prevent this problem, it is suggested that the voltage-divider current be maintained at at least 20 times the anode output current required from the photomultiplier tube.

Figure 21: Schematic Diagrams of Voltage-Divider Networks

(a) Basic arrangement for DC operation



(b) For pulse operation

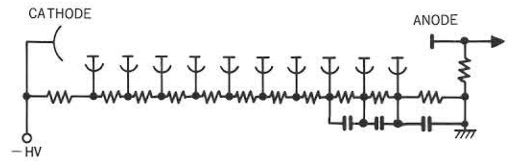
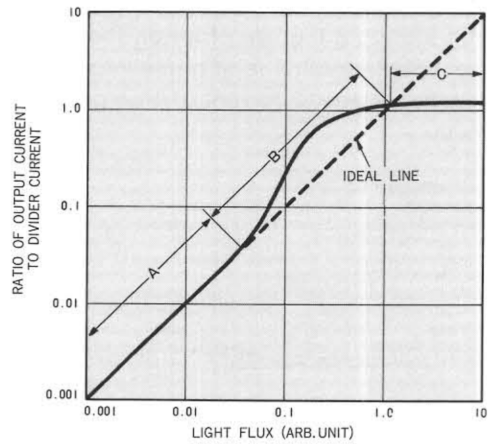


Figure 22: Response of a PMT Using Voltage Divider (a)



Generally high output current is required in applications where the input light is in the form of pulses. In order to maintain dynode potentials at a constant value during pulse durations and obtain high peak currents, large capacitors are used as shown in Figure 20 (b). The capacitor values depend on the output charge. If linearity of better than 1% is needed, the capacitor value between the last dynode and the anode should be at least 100 times the output charge per pulse, as follows:

$$C > 100 \frac{I \cdot t}{V} \quad \text{(farads)}$$

where I is the peak output current in amperes, t is the pulse width in seconds, and V is the voltage across the capacitor in volts.

Hamamatsu provides socket assemblies incorporating voltage-divider networks. They are compact, rugged, and carefully engineered to minimize electric leakage. (See page 66.)

Ground Polarity and HA Coating

The general technique used for voltage divider circuits is to ground the anode with a high negative voltage applied to the cathode. This scheme eliminates the potential difference between the external circuit and the anode, facilitating the connection of such circuits as ammeters or current-to-voltage conversion operational amplifiers to the photomultiplier tube. However, when a grounded anode configuration is used, bringing a grounded metallic holder or magnetic shield case near the bulb of the tube can cause electrons to strike the inner bulb wall, resulting in the generation of noise. Also, for head-on type photomultiplier tubes, if the faceplate or bulb near the photocathode is grounded, the slight conductivity of the glass material causes a current to flow between the photocathode (which has a high negative potential) and ground. This may cause electrolysis of the photocathode, leading to the danger of significant deterioration. For this reason, when designing the housing for a photomultiplier tube and when using an electrostatic or magnetic shield case, extreme care is required.

In addition, when using foam rubber or similar material to mount the tube in its housing, it is essential that material having sufficiently good insulation properties be used. This problem can be solved by applying a black conductive layer around the bulb and connecting to the cathode potential (called HA Coating), as shown in Figure 24. However, in scintillation counting, it is often impossible to use this technique, since the grounded scintillator is in intimate contact with the photomultiplier tube. In such cases, it is recommended that the cathode be grounded, as shown in Figure 23, with a high positive voltage applied to the anode. Using this scheme, a coupling capacitor C is used to separate the high positive voltage applied to the anode from the signal, making it impossible to obtain a DC signal output.

Figure 23: Cathode Ground Scheme

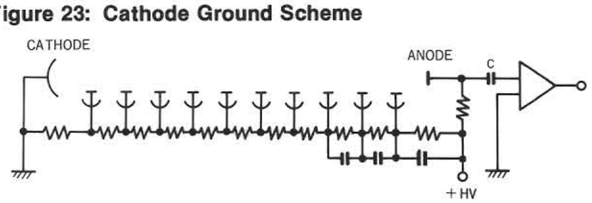
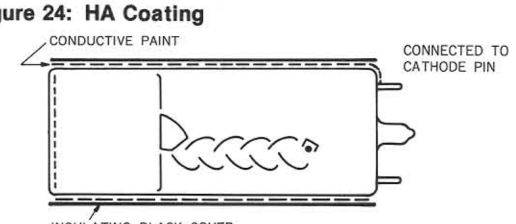


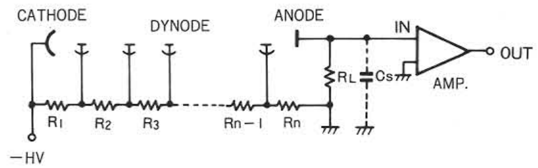
Figure 24: HA Coating



LOAD RESISTANCE

Since the output of a photomultiplier tube is a current signal and the type of external circuit to which photomultiplier tubes are usually connected has voltage inputs, a load resistance is used to perform a current-voltage transformation. This section describes considerations to be made when selecting this load resistance. Since for low output current levels, the photomultiplier may be assumed to act as virtually an ideal constant-current source, the load resistance can be made arbitrarily large, thus converting a low-level current output to a high-level voltage output. In practice, however, using very large values of load resistance creates the problems of deterioration of frequency response and output linearity described below.

Figure 25: Output Circuit for PMT

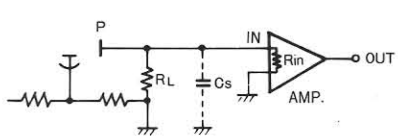


If, in the circuit of Figure 25, we let the load resistance be R_L and the total of the capacitance of the photomultiplier tube anode to all other electrodes, including such stray capacitance as wiring capacitances be C_S, the cutoff frequency f_C is expressed by the following relationship.

$$f_C = \frac{1}{2\pi C_S R_L}$$

From this relationship, it can be seen that, even if the photomultiplier tube and amplifier have very fast response, response will be limited to the cutoff frequency f_C of the output circuit. Anode effect of large load resistance is on linearity of the output current with respect to intensity of incident light. If the load resistance is made large, at high current levels the voltage drop across R_L becomes large, causing the potential difference between the last dynode stage and the anode to drop. This increases the effect of the space charge and lowers the efficiency of the anode in collecting electrons. In effect, the output becomes saturated above a certain current, resulting in a loss of linearity.

Figure 26: Amplifier Internal Resistance



In Figure 26, let us consider the effect of the internal resistance of the amplifier. If the load resistance is R_L and the input impedance of the amplifier is R_{in}, the combined parallel output resistance of the photomultiplier tube, R_O, is given by the following relationship.

$$R_O = \frac{R_L \cdot R_{in}}{R_L + R_{in}}$$

This value of R_O, less than the value of R_L, is then the effective load resistance of the photomultiplier tube. If, for example, $R_L = R_{in}$, the effective load resistance is 1/2 that of R_L alone. From this we see that the upper limit of the load resistance is actually the input resistance of the amplifier and that making the load resistance much greater than this value does not have significant effect. While the above description assumed the load and input impedances to be purely resistive, in practice, stray capacitances, input capacitance, and stray inductances influence phase relationships. Therefore, as frequency is increased these circuit elements must be considered as compound impedances rather than pure resistances.

From the above, three guides can be derived for use in selection of the load resistance:

1) In cases in which frequency response is important, the load resistance should be made as small as possible.
2) In cases in which output linearity is important, the load resistance should be chosen such that the output voltage is below several volts.
3) The load resistance should be less than the approximate input impedance of the external amplifier.

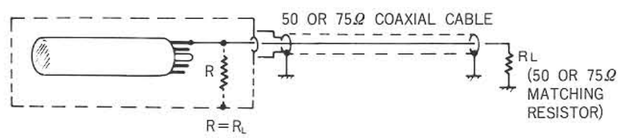
HIGH-SPEED OUTPUT CIRCUIT

For the detection of high-speed and pulsed light signals, a coaxial cable is used to make the connection between the photomultiplier tube and the electronic circuit, as shown in Figure 27. Since commonly used cables have characteristic impedances of 50 Ω or 75 Ω, this cable must be terminated in a pure resistance equivalent to the characteristic impedance to provide impedance matching and ensure distortion-free transmission for the signal waveform. If a matched transmission line is used, the impedance of the cable as seen by the photomultiplier tube output will be the characteristic impedance of the cable, regardless of the cable length, and no distortion will occur in signal waveforms.

If proper matching at the signal receiving end is not achieved, the impedance seen at the photomultiplier tube output will be a function of both frequency and cable length, resulting in significant waveform distortion. Such mismatched conditions can be caused by the connectors used as well, so that the connector to be used should be chosen with regard given to the frequency range to be used, to provide a match to the coaxial cable.

When a mismatch at the signal receiving end occurs, all of the pulse energy from the photomultiplier tube is not dissipated at the receiving end, but is partially reflected back to the photomultiplier tube. While this reflected energy will be fully dissipated at the photomultiplier tube if an impedance match has been achieved at the tube, if this is not the case, since the photomultiplier tube itself acts as an open circuit, the energy will be reflected and, thus, returned to the signal-receiving end. Since part of the pulse makes a round trip in the coaxial cable and is again input to the receiving end, this reflected signal is delayed with respect to the main pulse and results in waveform distortion (so called ringing phenomenon). To prevent this phenomenon, in addition to providing impedance matching at the receiving end, it is necessary to provide a resistance matched to the cable impedance at the photomultiplier tube end as well. If this is done, it is possible to virtually eliminate the ringing caused by an impedance mismatch, although the output pulse height of the photomultiplier tube is reduced to one-half of the normal level by use of this impedance matching resistor.

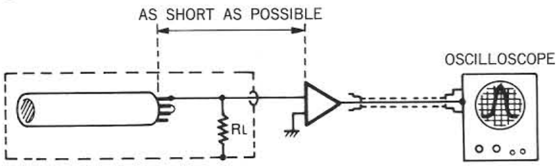
Figure 27: High-Speed Output Circuit



In Figure 28, let us consider waveform observation of high-speed pulses using an oscilloscope. This type of operation requires a low load resistance. Since, however, there is a limit to the oscilloscope sensitivity, an amplifier is required.

For cables to which a matching resistor has been connected, there is an advantage that the cable length does not affect the characteristics of the cable. However, since the matching resistance is very low compared to the usual load resistance, the output voltage becomes too small. While this situation can be remedied with an amplifier of high gain, the inherent noise of such an amplifier can itself be detrimental to measurement performance. In such cases, the photomultiplier tube can be brought as close as possible to the amplifier and a load resistance as large as possible should be used (consistent with preservation of frequency response), to achieve the desired input voltage.

Figure 28: Waveform Observation Using Oscilloscope



It is relatively simple to implement a high-speed amplifier using a wideband video amplifier or pulse-type ICs. Recent improvements in the availability of a variety of types of such ICs and price reductions have made this possible. There are, however, various problems concerned with characteristics (particularly noise performance) when using ICs, such problems requiring sufficient care in measurement system design.

As the pulse repetition frequency increases, baseline shift creates one reason for concern. This occurs because the DC signal component has been eliminated from the signal circuit by coupling with a capacitor which does not pass DC. If this occurs, the reference zero level observed at the last dynode stage is not the actual zero level. Instead, the apparent zero level is the time-average of the positive and negative fluctuations of the signal waveform. This will vary as a function of the pulse density, and is known as baseline shift. Since the height of the pulses above this baseline level is influenced by the repetition frequency, this phenomenon is of concern when observing waveforms or discriminating pulse levels.

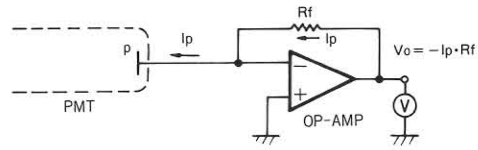
OPERATIONAL AMPLIFIERS

In cases in which a high-sensitivity ammeter is not available, the use of an operational amplifier will enable measurements to be made using an inexpensive voltmeter. This technique relies on converting the output current of the photomultiplier tube to a voltage signal. The basic circuit is as shown in Figure 29, for which the output voltage, V_O, is given by the following relationship.

$$V_O = -R_f \cdot I_p$$

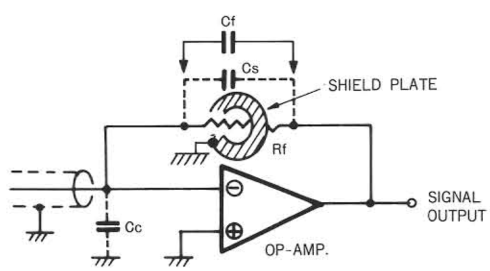
This relationship is derived for the following reason. If the input impedance of the operational amplifier is extremely large, and the output current of the photomultiplier tube is allowed to flow into the input terminal of the amplifier, most of the current will flow through R_f, and subsequently to the operational amplifier output circuit. Therefore, the output voltage, V_O, is given by the expression $-R_f \times I_p$. When using such an operational amplifier it is, of course, not possible to increase the output voltage without limit, the actual maximum output being approximately equal to the operational amplifier power supply voltage. At the other end of the scale, for extremely small currents, limitations are placed by the operational amplifier offset current (I_{OS}), the quality of R_f, and other factors such as the insulation materials used.

Figure 29: Current-Voltage Transformation Using Operational Amplifier



If the operational amplifier has an offset current (I_{OS}), the above-described output voltage becomes $V_O = -R_f (I_p + I_{OS})$, the offset current component being superimposed on the output. Also, the magnitude of temperature drift may create a problem. In general, a metallic film resistor is used for the resistance R_f, and for high resistance values, a vacuum-sealed type is used. Carbon resistors, with their highly temperature-dependent resistance characteristics, are not suitable for this application. When inputting such extremely low level currents as 100 pA and below, in addition to the considerations described above, the materials used in the circuit implementation require care as well. For example, materials such as bakelite are not suitable, more suitable materials being Teflon, polystyrol, or steatite. In addition, low-noise cables should be used, since general-purpose coaxial cables exhibit noise due to mechanical changes.

Figure 30: Frequency Compensation of Operational Amplifier



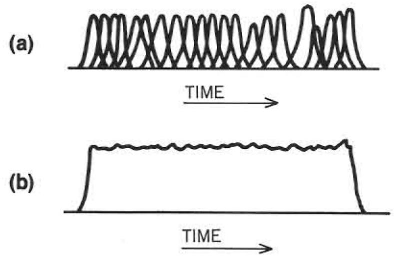
In Figure 30, if a capacitance C_f (including any stray capacitances) exists in parallel to the resistance R_f, the circuit exhibits a time constant of ($R_f \times C_f$), so that response speed is limited to this time constant. This is a particular problem if R_f is made large. Stray capacitance can be reduced by passing R_f through a hole in a shield plate. When using coaxial signal input cables, since the cable capacitance C_c and R_f are in the feedback loop, oscillations may occur and noise may be amplified. While the method of avoiding this is to connect C_f in parallel to R_f, to reduce gain at high frequencies, this, as described above, creates a time constant of $R_f \times C_f$ which limits the response speed.

APPENDIX

1) Photon Counting

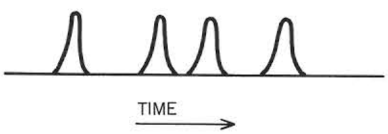
Photon counting is one effective way to use a photomultiplier tube for measuring very low light. It is widely used in astronomical photometry and fluorescence spectroscopy. In the usual application, a number of photons enters the photomultiplier tube and creates an output pulse train like (a) in Figure 31. The actual output obtained by the measurement circuit is a DC with fluctuation as shown at (b).

Figure 31: Overlapping Output Pulses



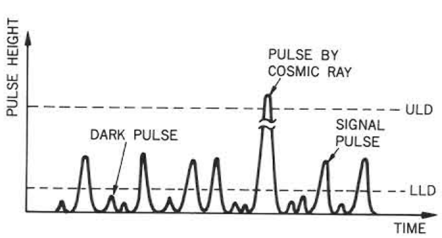
When the light intensity becomes so low that the incident photons are separated as shown in Figure 32. This condition is called single photon event. The number of output pulses is in direct proportion to the amount of incident light and this pulse counting method has advantages in S/N ratio and stability over the DC method averaging all the pulses. This pulse counting technique is the photon counting method.

Figure 32: Single Photon Event



Since the photomultiplier tube output contains a variety of noise pulses in addition to the signal pulses representing photoelectrons as shown in Figure 33, simply counting the pulses without some form of noise elimination will not result in an accurate measurement. The most effective approach to noise elimination is to investigate the height of the output pulses.

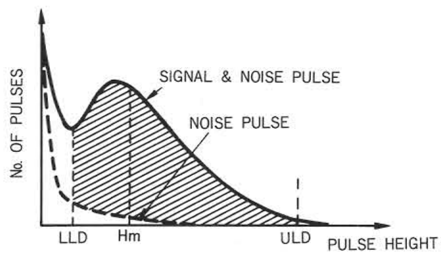
Figure 33: Output Pulse and Discrimination Level



A typical pulse height distribution (PHD) of output of photomultiplier tubes is shown in Figure 34. In this PHD, the lower level discrimination (LLD) is set at the valley and the upper level discrimination (ULD) at the foot. Most pulses smaller than the LLD are noise and pulses larger than the ULD result from cosmic rays, etc. Therefore, by counting pulses between the LLD and ULD, accurate light measurements are made possible. In the PHD, Hm is the mean height of pulses. It is recommended that the LLD be set at 1/3 of Hm and the ULD at triple Hm.

Considering the above, clear definition of the peak and valley in the PHD is a very significant characteristic for photomultiplier tubes for use in photon counting. All of Hamamatsu photomultiplier tubes selected for photon counting are supplied with such PHD data.

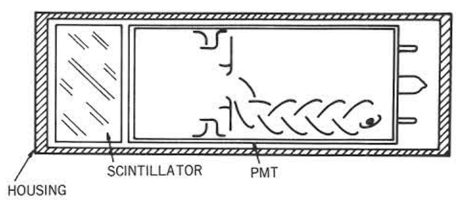
Figure 34: Typical Pulse Height Distribution



2) Scintillation Counting

Scintillation counting is one of the most common and effective methods in detecting radiation particles. It uses a photomultiplier tube coupled to a scintillator which produces light by incidence of radiation particles.

Figure 35: Diagram of Scintillation Detector



In radiation particle measurements, there are two parameters that should be measured. One is the energy of individual particles and the other is the amount of particles. When radiation particles enter the scintillator, it produces light flashes in response to each particle. The amount of flash is proportional to the energy of the incident particle and individual light flashes are detected by the photomultiplier tube. Consequently, the output pulses obtained from the photomultiplier tube contain information on both the energy and amount of pulses, as shown in Figure 36.

By analyzing these output pulses using a multichannel analyzer (MCA), a pulse height distribution (PHD) or energy spectrum as shown in Figure 37 is obtained. From the PHD, the amount of incident particles at various energy levels can be measured. For the PHD, it is very important to have distinct peaks at each energy level. This is evaluated as pulse height resolution and is the most significant characteristic in radiation particle measurements. Figure 38 shows the definition of pulse height resolution for a ^{137}Cs source.

Figure 36: Incident Particles and PMT Output

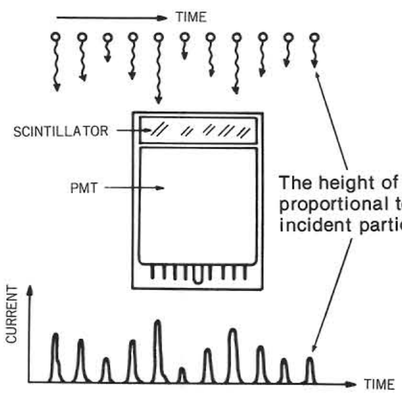


Figure 37: Pulse Height Distribution (Energy Spectrum)

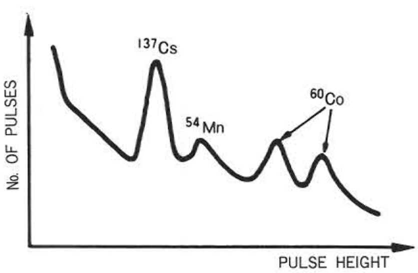
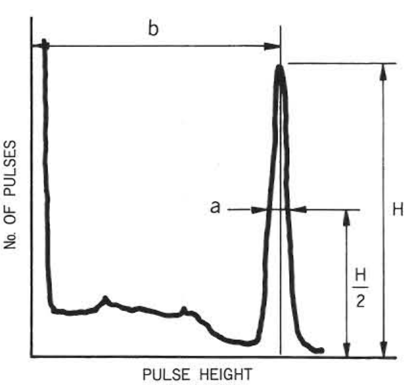
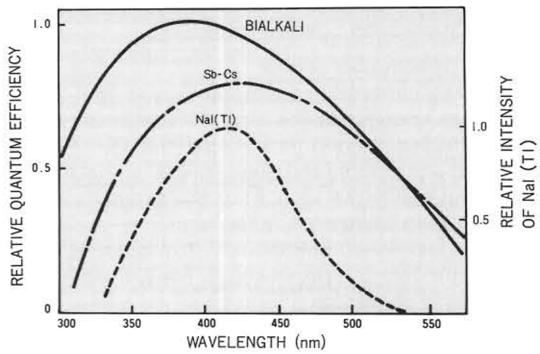


Figure 38: Definition of Pulse Height Resolution



$$\text{Pulse Height Resolution} = \frac{a}{b} \times 100\ (\%)$$

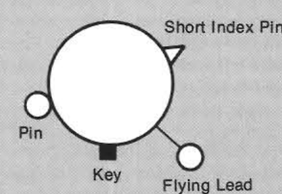
Figure 39: Spectral Response of PMT and Spectral Emission of NaI (Tl) Scintillator



Pulse height resolution is mainly determined by the quantum efficiency of the photomultiplier tube in response to the scintillator emission. It is necessary to choose the tube whose spectral response matches the scintillator emission. For thallium-activated sodium iodide, NaI(Tl) which is the most popular scintillator, head-on type photomultiplier tubes with a bialkali photocathode are widely used. Hamamatsu has a 30-page catalog "Photomultiplier Tubes for Scintillation Counting and High Energy Physics" available from our sales office.

BASING DIAGRAM SYMBOLS

All basing diagrams show terminals viewed from the base end of the tube.



DY	: Dynode
G (F)	: Grid (Focusing Electrode)
ACC	: Grid (Accelerating Electrode)
K	: Photocathode
P	: Anode
SH	: Shield
IC	: Internal Connection (Do not use)
NC	: No Connection (Do not use)

Selection Guide by Applications

Applications	Required Major Characteristics	Applicable PMT
Spectroscopy		
Absorption Spectroscopy		
UV/Visible/IR Spectrophotometer When light passes through a substance, the light energy causes changes in the electron energy of the substance, resulting in partial energy loss. This is called absorption and gives analytical data. In order to determine the amount of the sample substance, it is irradiated while the light wavelength is scanned continuously. The spectral intensity of the light passing through the sample is detected by a photomultiplier tube.	1) High stability 2) Low noise 3) Wide spectral response 4) High cathode sensitivity 5) Low hysteresis 6) Wide dynamic range	1P28A, R268, R372, R446, R456, R928, R955, etc.
Atomic Absorption Spectrophotometer This is widely used in the analysis of minute quantities of metallic elements. For each element to be analyzed, a special elementary hollow cathode lamp is used to irradiate a sample which is atomized by flaming, etc. A photomultiplier tube detects the light passing through the sample to measure the amount of absorption, which is compared with a standard sample measured in advance.		R268, R456, R955, R1503, etc.
Emission Spectroscopy		
Photoelectric Emission Spectrophotometer This system enables rapid qualitative and quantitative chemical analysis by measuring the wavelength and intensity of characteristic spectral emission lines of elements when an external energy (electric spark, arc, etc.) is applied to the sample for excitation. Several photomultiplier tubes are arranged in the detection section to detect multiple spectral emission lines simultaneously.	1) High stability 2) Low dark current 3) High sensitivity	1P21, 1P28, R106, R166, R300, R306, R427, R787, R889, R928, R955, R1414, R1657, etc.
Fluorescence Spectrophotometer The fluorescence spectrophotometer is used in biological science, particularly in molecular biology. When an excitation light is applied, some substances emit light with a wavelength longer than that of the excitation light. This light is called fluorescence. The intensity and spectral characteristics, etc. of the fluorescence are measured by a photomultiplier tube, and the substance is analyzed qualitatively and quantitatively.		R212, R268, R372, R777, R928, R1527, etc.
Raman Spectroscopy When monochromatic light strikes a substance and scatters, Raman scattering also occurs. Raman scattering occurs at a different wavelength from the excitation light, at 90 degrees to the excitation. Since the difference is characteristic of the molecules, the spectral measurement of Raman scattering provides information on molecular structure and other chemical analysis. Raman scattering is extremely weak and a sophisticated optical system is used for measurement, thus the photomultiplier tube is used in the photon counting mode.	1) High quantum efficiency 2) Less dark current pulses 3) High current amplification 4) Good single photon detectivity	1P21P, R212P, R316, R406P, R427P, R464, R585, R647-04, R649, R928P, R943-02, R1332, R1333, R1414P, R1463-01, R1527P, R2371P, etc.
Others ● Liquid or Gas Chromotography ● X-ray Applied Analysis System ● Electron Microscope		R212, R446, R928, R1516, etc. R268, R580, R647-01, R1166, etc. R268, R580, R647, etc.

Applications	Required Major Characteristics	Applicable PMT
Pollution Monitoring		
Dust Counter A dust counter measures the density of particles floating in the atmosphere or inside rooms. It makes use of light scattering or absorption of beta-rays by particles.	1) Low dark noise, low spike noise 2) High quantum efficiency 3) High current amplification	R105, R212, 931B, R1516, etc.
Turbidimeter A turbidimeter measures turbidity of a solution containing floating particles using a photomultiplier tube. It utilizes light scattering and transmission as a light beam passes through the solution.		R105, R212, R268, 931B, R1516, R1924, 6199, etc.
Door Monitor This device installed at exits of atomic power plants, to check for radiation contamination of personnel leaving the area. The weak light emitted when radiations pass through the scintillator is detected by a photomultiplier tube.	1) High energy resolution 2) Low dark noise, low spike noise 3) High quantum efficiency 4) High current amplification	R329, R331-05, R434, R877-01, R980, R1307, R1306, R1924, etc.
Others ● NOx meters, SOx meters	1) High cathode sensitivity at wavelength of interest 2) Low dark current 3) Good temperature characteristic	R928, R669, R1017, R1527, R2228, etc.
Lasers		
Laser Radar The laser radar is used in such applications as atmospheric measurement which uses a highly-accurate range finding or aerosol scattering. Photomultiplier tubes are used when the objective wavelength is in the ultraviolet to visible range, or the near infrared range.	1) Fast response time 2) Low noise 3) High current amplification	R928, R1332, R1564U, R1645U, R1828-01, R2024U, R2083 (H2431), R2287U, R2809U, etc.
Laser Gyroscope Conventional mechanical gyroscopes use a principle in which a top keeps its axis unidirectional, but these systems are large-scale and expensive. Using a laser gyroscope allows a small-size system which is less expensive and affords a faster response. It is expected to cover a wide range of applications, from airplanes and ships to cars and robots.		
Fluorescence Lifetime Measurement The laser is used as an excitation light for fluorescence lifetime measurement. The molecular structure of a substance can be studied by measuring temporal intensity changes in fluorescence.		

Applications	Required Major Characteristics	Applicable PMT
Biology		
Cell Sorter This instrument is designed to sort cells of a special class. Cells labelled by a fluorescent matter are irradiated with a laser beam. The fluorescence or scattered light from the cells is then measured by a photomultiplier tube.	1) High quantum efficiency 2) High stability 3) Low dark current 4) High sensitivity 5) Independent of polarized light	R928, R1477, R1923, etc.
Fluorometer A fluorometer is used for chemical analysis of cells or other chemical substances. This is performed by measuring the fluorescence or scattered light from cells and chromosomes, including fluorescent spectra, fluorescent quantum yield, fluorescent anisotrophy (polarization), fluorescent lifetime, etc.		R372, R928, R1477, R1923, etc.
Medical Applications		
Radioimmunoassay This is a method of measuring tiny amounts of insulin, hormones, drugs, etc. in the bloodstream, using antigen/antibody reaction characteristics. Photomultiplier tubes are used to measure the radioactivity emitted by antigens tagged by radioisotopes.	1) High energy resolution 2) High stability 3) Low noise	R268, R580, R877, R878, R980, R1166, R1306, R1307, R1612, 6199, etc.
Gamma Camera The gamma camera takes an image of a radioisotope injected into the blood stream of a patient, and is used for locating abnormalities. Its detection section uses a large diameter NaI(Tl) scintillator and light guide, plus an array of photomultiplier tubes.	1) High energy resolution 2) Good uniformity 3) High stability 4) Uniform gain between tubes	R878, R980, R1306, R1307, R1534-01, R1537-01, R1538-01, R1548, R1847-07, R1848-07, etc.
Positron CT The positron CT provides tomographic images based on coincident gamma-ray emission accompanying annihilation of a positron emitted from a tracer radioisotope (^{11}C, ^{15}O, ^{13}N, ^{18}F, etc.). Photomultiplier tubes coupled to scintillators are used to detect gamma-rays.	1) High energy resolution 2) High current amplification 3) Good C.R.T. (Coincidence Resolving Time) 4) Compact size	R647, R1450, R1535, R1548, R1635, R2059, R2076, R2102, R2248, R2496, R2497, R3172, etc.
Liquid Scintillation Counter One of major applications of the liquid scintillation counter is in tracer analysis in biochemistry. A sample containing radioisotopes is dissolved in a solution containing an organic scintillator, and it is placed in the center between a pair of photomultiplier tubes. These tubes simultaneously detect the emission of the organic scintillator. As ^{3}H, ^{14}C, ^{32}P, etc. have a tenfold difference in energy between them, each type can be distinguished independently.	1) Low noise of thermionic emission 2) Less glass scintillation of tubes 3) Fast response time 4) High quantum efficiency 5) High pulse linearity 6) High current amplification	R331, R329, R331-05, etc.
Others ● X-ray phototimer	1) High sensitivity 2) Low dark current 3) High stability	1P21, R105, R300, R444, 931A, 931B, R1413, R1414, etc.

Applications	Required Major Characteristics	Applicable PMT
High Energy Physics		
Detectors Peripheral to Accelerator		
Hodoscope Photomultiplier tubes are coupled to the ends of long, thin plastic scintillators arranged orthogonally in two layers. They can measure the time and position at which charged particles pass through the scintillators.	1) Fast response time 2) High pulse linearity 3) High energy resolution 4) Immunity to magnetic fields 5) Compact size	**R647-01, R1166, R1450, R1635, R2496, R3082 (H3171), etc.**
TOF Counter Two counters are arranged along a path of charged particles with each counter consisting of a scintillator and a photomultiplier tube. The velocity of the particles is measured by time difference between the two counters.		**R329 (H1161), R1332, R1450, R1635, R1828-01 (H1949), R2059, R2083 (H2431), etc.**
Cherenkov Counter A Cherenkov counter detects electrons, positrons and gamma-rays from among the particles generated by the collision reaction of electrons and positrons, and measures their energy. For example, in a gas Cherenkov counter, the photomultiplier tube measures the Cherenkov light emitted as particles pass through the gas.	1) High energy resolution 2) High pulse linearity 3) Fast response time 4) Immunity to magnetic fields	**R329 (H1161), R2059, R2496, R1584, R1836, etc.**
Calorimeter The calorimeter measures the direction and energy of photons, electrons and positrons among the particles emitted from the collision reaction of electrons and positrons.		**R594, R2021, R2238, R2490-01, Triode Tubes (R2148, R2184, R2046), Tetrode Tubes (R2149, R2185, R2186), etc.**
Proton Decay Experiment, Cosmic Rays Detection		
Proton Decay Experiment In the experiments in proton decay observation taking place in Japan, a thousand 20" diameter photomultiplier tubes have been installed covering all directions of a huge tank storing about 3000 tons of pure water. They intend to detect the Cherenkov light emitted when protons contained in the pure water decay.	1) Large photocathode area 2) Fast response time 3) High stability 4) Low noise	**R1408, R1449, R2218, etc.**
DUMAND System The DUMAND (Deep Underwater Muon and Neutrino Detection) System was developed with international cooperation to detect muons and neutrinos which fall from space. An array of large-diameter photomultiplier tubes is installed on the ocean floor offshore from Hawaii, about 5000 meters deep, to measure the Cherenkov light that occurs from the interaction of high-energy muons and neutrinos with sea water.		**R1408, R1449, R2218, etc.**
Air Shower Counter When cosmic rays collide with the earth's atmosphere, secondary particles are created by the interaction of the cosmic rays and atmospheric atoms. These secondary particles generate more secondary particles, which continue to increase in a geometrical progression. This is called an air shower. The Cherenkov light emitted in this air shower is detected by photomultiplier tubes lined up in a lattice array on the ground.		**R329 (H1161), R580, R1250, etc.**

Applications	Required Major Characteristics	Applicable PMT
Resource Inquiry		
Oil Well Logging Oil well logging is one means of finding out the position and scale of oil fields. A probe containing a radiation source, scintillator, and photomultiplier tube is lowered deep into a bore hole, and scattered rays or natural radiations from the geological formation are detected and analyzed.	1) Stable operation at high temperatures up to 175°C 2) Rugged structure 3) Good plateau characteristic at high temperatures	**R1044, R1281, R1282, R1288, R1317-05, R1591, R1640, R1705, etc.**
Process Control		
Thickness Meter Using a radiation source, photomultiplier tube and scintillator, a product thickness can be measured on production lines for paper, plastic, steel sheet, etc. Beta-rays are used as a radiation source in measurement of products with a small surface density, such as rubber, plastic, and paper. Gamma-rays are used for products with a large surface density, like steel sheeting. (X-ray fluorescence spectrometers are used in measurement of film thickness for plating, evaporation, etc.)	1) Wide dynamic range 2) High energy resolution 3) Low hysteresis	**R268, R878, 7696, etc.**
Laser Scanner This is widely used for semiconductor wafer inspection and pattern recognition in semiconductor mask alignment. For wafer inspection, the wafer is scanned by a laser beam, and scattered light caused by dirt or defects is detected by a photomultiplier tube.	1) High quantum efficiency at wavelengths of interest 2) Good spatial uniformity 3) Low dark current	**R268, R374, R647, R878, R928, R1387, R1463, R1477, R1513, 7696, etc.**
Photography and Printing		
Color Scanner To prepare color pictures and photographs for printing, the color scanner is used to separate the original colors into the three primary colors and black. It combines 4 photomultiplier tubes and special mirrors which reflect only a specific color.	1) High quantum efficiency at wavelengths of R.G.B. 2) Fast fall time 3) Low dark current 4) High stability 5) Good repeatability with change in input signal	**R268, R372, R434, R446, R905, R1387, R1759, etc.**
Flying Spot Scanner The flying spot scanner converts a motion picture film or slide transparency into television signals. It uses a special CRT called a flying spot tube which provides a spot light source forming a raster. The raster is focused onto the film, and the transmitted or reflected light is detected by photomultiplier tubes with red, green, and blue filters. These are then converted into television signals. At present, the flying spot scanning technique is also applied for semiconductor mask inspection.	1) Low dark current, low spike noise 2) High cathode sensitivity (in R.G.B. for color production) 3) Wide dynamic range	**PM55, R268, R446, R550, R878, R906, 931A, R1387, R1759, 7696, etc.**

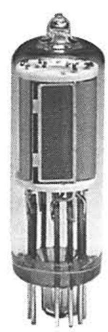
Applications	Required Major Characteristics	Applicable PMT
Plasma		
Plasma Observation Photomultiplier tubes are being used in the electron density and electron temperature measurement system for plasma in the tokamak-type nuclear fusion test reactor in Japan. Photomultiplier tubes and MCPs are also used in similar measurements for plasma using Thompson scattering and the Doppler effect, in observation of spatial distribution of plasma, and in measurements of impurities in plasma for the purpose of impurity and ion control.	1) High detectivity in low-light-level 2) High quantum efficiency 3) Gating function	R943-02, R1333, etc.
Space		
Measurement of Astronomical X-rays X-rays from outer space include information on the enigmas of space. Satellite-borne X-ray detectors consisting of a gas scintillation proportional counter tube and a photomultiplier tube are used for measurements of astronomical x-rays from supernovas, etc.	1) High energy resolution 2) Rugged structure	R1306, R1307, R1847-07, R1848-07, R1924, etc.
Measurement of Scattered Light from Fixed Stars and Interstellar Dust Ultraviolet rays from space contain a lot of information about the surface temperature of the stars and interstellar substances. However, these ultraviolet rays are absorbed by the earth's atmosphere, so it is impossible to measure them from the earth surface. Photomultiplier tubes are mounted in rockets or artificial satellites, to measure ultraviolet rays with a wavelength shorter than 300 nm.	1) Rugged structure 2) Sensitivity in vacuum UV to UV range (solar blind spectral response)	R427, R972, R1080, R1081, R1220, R1259, R1459, R1460, R1689-02, etc.
Mass Spectroscopy and Solid Surface Analysis		
Solid Surface Analysis The composition and structure of surface matter can be studied by irradiating a narrow beam of electrons, ions, light, X-rays, etc. onto a surface and measuring the electrons, ions, X-rays, etc. that are produced. With the progress of the semiconductor industry, this kind of technology permits comprehensive measurement of semiconductors, including defects, surface analysis, adhesion, and density profile. Electrons, ions, and X-rays are measured with electron multipliers and MCPs.	1) Stable in air 2) Long term stability 3) High current amplification 4) Low noise	Electron Multipliers, MCP

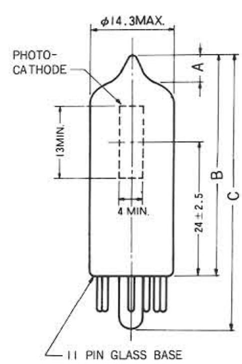
Side-On Type Photomultiplier Tubes

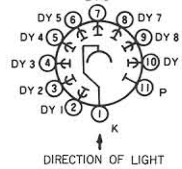
Ⓐ Type No.	Remarks	Spectral Response Ⓑ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	Ⓒ Photocathode Material	Ⓓ Window Material	Ⓔ Outline No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket	Maximum Ratings Ⓗ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓙ Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
1/2 inch (13 mm) Dia. Compact Types													
R1657	Solar blind response	250S	160~320	200	Cs-Te	Q	❶	CC/9	E678-11H	1250	0.01	—	—
R1413	S-5 response, general purpose	350U (S-5)	185~650	340	Sb-Cs	U	❶	CC/9	E678-11H	1000	0.01	20	40
R1414	High gain and low dark current variant of R1413				Sb-Cs	U	❶	CC/9	E678-11H	1250	0.01	20	40
*R2371	New photocathode and low dark current variant of R1414	456U	185~680	375	L Bi	U	❶	CC/9	E678-11H	1250	0.01	20	50
*R2371-02	Photon counting type of R2371				L Bi	U	❶	CC/9	E678-11H	1250	0.01	20	50
R1546	Multialkali photocathode, wide spectral response	550U	185~850	530	M	U	❷	CC/9	E678-11H	1000	0.01	50	80
R1547	High sensitivity and low dark current variant of R1546				M	U	❷	CC/9	E678-11H	1250	0.01	100	150
1/2 inch (13 mm) Dia. Types with Anode Cap													
R427	Solar blind response	250S	160~320	200	Cs-Te	Q	❸	CC/9	E678-11H	1250	0.01	—	—
R444	S-5 response, general purpose	350U (S-5)	185~650	340	Sb-Cs	U	❸	CC/9	E678-11H	1000	0.01	20	40
R300	High gain and low dark current variant of R444				Sb-Cs	U	❸	CC/9	E678-11H	1250	0.01	20	40
R306	Variant of R300 with synthetic silica window	350S (S-19)	160~650	340	Sb-Cs	Q	❸	CC/9	E678-11H	1250	0.01	20	40
R500	Variant of R300 with multialkali photocathode	550U	185~850	530	M	U	❸	CC/9	E678-11H	1000	0.01	50	80
R889	High sensitivity variant of R500				M	U	❸	CC/9	E678-11H	1250	0.01	100	150
R1503	Variant of R889 with synthetic silica window	550S	160~850	530	M	Q	❸	CC/9	E678-11H	1250	0.01	100	150

Ⓐ * : Newly listed in this catalog.
Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓒ Photocathode Materials
  L Bi : Low noise bialkali
  M : Multialkali
Ⓓ Window Materials
  Q : Synthetic silica
  U : UV glass
Ⓔ Basing diagram symbols are explained on page 17.
Ⓕ Dynode Structure
  CC : Circular-cage
Ⓖ A socket will be supplied with a tube.
Ⓗ The maximum ambient temperature range is −80 to +50°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
Ⓙ Averaged over any interval of 30 seconds maximum.
Ⓚ At the wavelength of peak response.
Ⓛ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓜ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓛ .
a: At 254 nm

❶ R1657, R1413, R2371 etc.







Bottom View

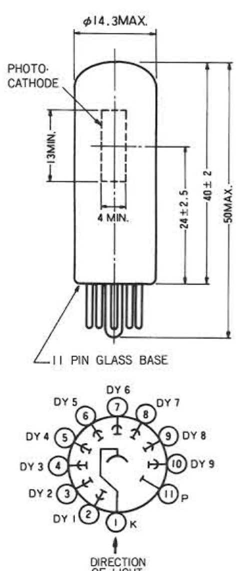
	R1657	Others
A	7 ± 2	5 ± 2
B	42 ± 2	40 ± 2
C	52 MAX.	50 MAX.

(at 25°C)

Cathode Sensitivity			Anode to Cathode Supply Voltage Ⓛ	Anode Characteristics Ⓜ								Notes	Type No. Ⓐ
				Anode Sensitivity			Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response			
				Luminous		Radiant Typ. Ⓚ							
Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Radiant Typ. Ⓚ (mA/W)	(Vdc)	Min. (A/lm)	Typ. (A/lm)	(A/W)		Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)		
—	—	40[a]	1000 ⑩	—	—	1.0×10^5[a]	2.5×10^6	0.5	10	1.4	15		R1657
6.4	—	36	1000 ⑩	30	130	1.2×10^5	3.3×10^6	1	100	1.4	15		R1413
6.4	—	36	1000 ⑩	50	300	2.7×10^5	7.5×10^6	0.5	5	1.4	15	Silica window type (R1656) available.	R1414
6.4	—	60	1000 ⑩	30	100	1.2×10^5	2.0×10^6	0.1	2	1.4	15		R2371 *
6.4	—	60	1000 ⑩	30	100	1.2×10^5	2.0×10^6	0.05	0.5	1.4	15	Dark conts 10 cps (Typ.), 50 cps (Max.)	R2371-02 *
4.2	0.075	23	1000 ⑩	50	80	2.3×10^4	1.0×10^6	1	100	1.4	15		R1546
6.0	0.15	45	1000 ⑩	100	200	5.9×10^4	1.3×10^6	0.5	5	1.4	15		R1547
—	—	40[a]	1000 ⑩	—	—	1.0×10^5[a]	2.5×10^6	0.5	10	1.4	15		R427
6.4	—	36	1000 ⑩	30	130	1.2×10^5	3.3×10^6	1	100	1.4	15		R444
6.4	—	36	1000 ⑩	50	300	2.7×10^5	7.5×10^6	0.5	5	1.4	15		R300
6.4	—	36	1000 ⑩	50	300	2.7×10^5	7.5×10^6	0.5	7	1.4	15		R306
4.2	0.12	23	1000 ⑩	30	80	2.3×10^4	1.0×10^6	5	50	1.4	15		R500
6.0	0.15	45	1000 ⑩	100	200	5.9×10^4	1.3×10^6	1	50	1.4	15		R889
6.0	0.15	45	1000 ⑩	100	200	5.9×10^4	1.3×10^6	1	50	1.4	15		R1503

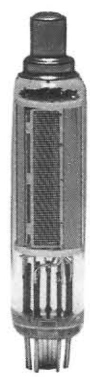
Unit: mm

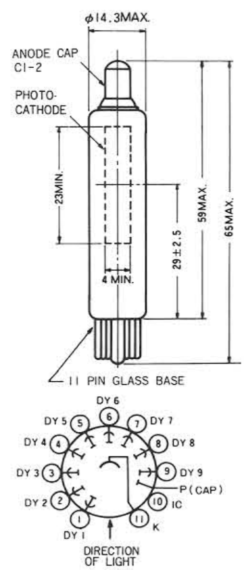
❷ R1546, R1547



Bottom View

❸ R427, R300, R889 etc.





Bottom View

Side-On Type Photomultiplier Tubes

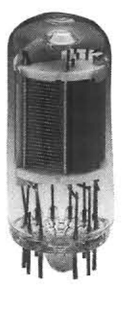
Ⓐ Type No.	Remarks	Spectral Response: Ⓑ Curve Code	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Ⓒ Photocathode Material	Ⓓ Window Material	Ⓔ Outline No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket	Ⓗ Maximum Ratings: Anode to Cathode Voltage (Vdc)	Ⓘ Maximum Ratings: Average Anode Current (mA)	Cathode Sensitivity, Luminous: Min. (μA/lm)	Cathode Sensitivity, Luminous: Typ. (μA/lm)
1-1/8 inch (28 mm) Dia. Type with Glass Base													
R906	For blue channel flying spot scanners	350K	300~650	400	Sb-Cs	K	❶	CC/9	E678-12C	1250	0.1	20	60
1-1/8 inch (28 mm) Dia. Types with UV to Visible Sensitivity													
931A	S-4 response, general purpose	350K (S-4)	300~650	400	Sb-Cs	K	❷	CC/9	E678-11A	1250	0.1	20	40
931B	Variant of 931A with bialkali photocathode, high stability	453K	300~650	400	Bi	K	❷	CC/9	E678-11A	1250	0.1	25	55
1P21	Medium gain and very low dark current variant of 931A	350K (S-4)	300~650	400	Sb-Cs	K	❷	CC/9	E678-11A	1250	0.1	20	40
R105	High gain variant of 1P21 with relaxed dark spec.				Sb-Cs	K	❷	CC/9	E678-11A	1250	0.1	25	40
R105UH	Ultra-high gain variant of R105				Sb-Cs	K	❷	CC/9	E678-11A	1000	0.1	30	50
1P28	S-5 response, general purpose	350U (S-5)	185~650	340	Sb-Cs	U	❷	CC/9	E678-11A	1250	0.1	20	40
R212	High gain and low dark current variant of 1P28				Sb-Cs	U	❷	CC/9	E678-11A	1250	0.1	20	40
R212UH	Ultra-high gain variant of R212				Sb-Cs	U	❷	CC/9	E678-11A	1000	0.1	30	50
R1527	Low noise bialkali photocathode	456U	185~680	375	L Bi	U	❷	CC/9	E678-11A	1250	0.1	20	60
*R2693	Semitransparent photocathode, low noise bialkali	403U	185~680	375	L Bi	U	❸	CC/9	E678-11A	1250	0.1	20	45
R106	Variant of R212 with synthetic silica window	350S (S-19)	160~650	340	Sb-Cs	Q	❷	CC/9	E678-11A	1250	0.1	20	40
R106UH	Ultra-high gain variant of R106				Sb-Cs	Q	❷	CC/9	E678-11A	1000	0.1	30	50
1P28A	Extended red S-5 response	351U	185~700	450	Sb-Cs	U	❷	CC/9	E678-11A	1250	0.1	25	70
R372	Red-enhanced bialkali photocathode	451U	185~730	340	Bi	U	❷	CC/9	E678-11A	1250	0.1	20	60
R905	Ultra-high gain, red-enhanced bialkali photocathode	452U	185~750	350	Bi	U	❷	CC/9	E678-11A	1000	0.1	50	80
R1516	Variant of 931B with UV glass Direct replacement for 1P28B	453U	185~650	400	Bi	U	❷	CC/9	E678-11A	1250	0.1	40	60
R1784	5-stage, high pulse linearity, fast time response	455U	185~680	420	Bi	U	❹	CC/5	E678-11A	2000	0.1	20	40

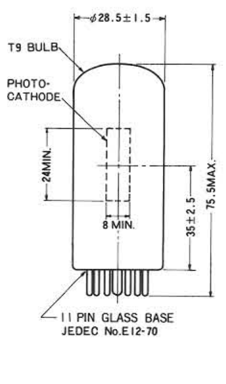
Ⓐ * : Newly listed in this catalog.
Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓒ Photocathode materials
- Bi : Bialkali
- L Bi : Low noise bialkali

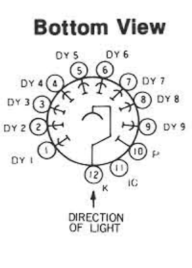
Ⓓ Window materials
- K : Borosilicate glass
- U : UV glass
- Q : Synthetic silica

Ⓔ Basing diagram symbols are explained on page 17.
Ⓕ Dynode Structure
- CC : Circular-cage

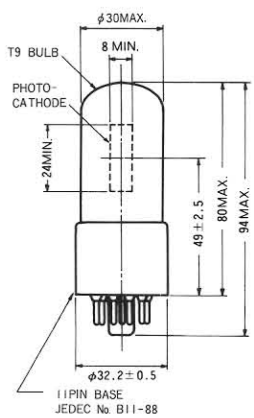
❶ R906

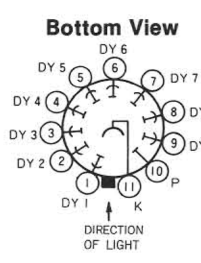






❷ 931A, 1P28, R106 etc.





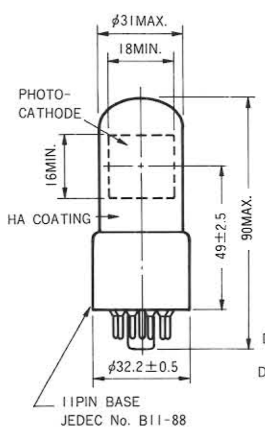
(at 25°C)

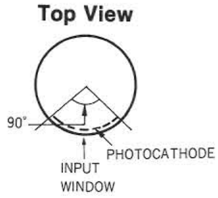
Cathode Sensitivity: Blue Typ. (µA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity: Luminous Min. (A/lm)	Anode Sensitivity: Luminous Typ. (A/lm)	Anode Sensitivity: Radiant Typ. (K) (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
7.5	—	72	1000 (10)	50	200	2.4×10^5	3.3×10^6	5	100	2.2	22		**R906**
5.0	—	48	1000 (10)	20	100	1.2×10^5	2.5×10^6	10	500	2.2	22		**931A**
7.1	—	60	1000 (10)	50	400	4.4×10^5	7.3×10^6	5	50	2.2	22		**931B**
5.0	—	48	1000 (10)	50	150	1.8×10^5	3.8×10^6	1	5	2.2	22		**1P21**
5.0	—	48	1000 (10)	50	400	4.8×10^5	1.0×10^7	2	10	2.2	22		**R105**
5.5	—	60	1000 (10)	1000	1500	1.8×10^6	3.0×10^7	1	50	2.2	22		**R105UH**
5.0	—	48	1000 (10)	20	200	2.4×10^5	5.0×10^6	5	100	2.2	22		**1P28**
5.0	—	48	1000 (10)	50	300	3.6×10^5	7.5×10^6	1	10	2.2	22		**R212**
5.5	—	60	1000 (10)	1000	1500	1.8×10^6	3.0×10^7	1	50	2.2	22		**R212UH**
6.4	0.005	67	1000 (10)	50	300	3.4×10^5	5.0×10^6	0.1	2	2.2	22	Photon counting type (R1527P) available.	**R1527**
7.0	—	60	1000 (10)	20	150	1.9×10^5	3.3×10^6	0.1	2	1.2	18	Photon counting type (R2693P) available.	**R2693 ***
6.5	—	48	1000 (10)	50	200	2.4×10^5	5.0×10^6	1	10	2.2	22		**R106**
7.0	—	60	1000 (10)	1000	1500	1.8×10^6	3.0×10^7	1	50	2.2	22		**R106UH**
6.5	0.01	56	1000 (10)	50	300	2.4×10^5	4.3×10^6	5	50	2.2	22	HA coating type (R282) available.	**1P28A**
6.5	0.02	61	1000 (10)	50	400	4.0×10^5	6.7×10^6	5	50	2.2	22		**R372**
8.0	0.03	79	600 (10)	20	100	—	1.3×10^6	1	30	2.8	28		**R905**
7.1	—	65	1000 (10)	100	300	3.3×10^5	5.0×10^6	2	20	2.2	22		**R1516**
5.0	—	48	600 (2)	—	0.12	—	3.0×10^3	0.05	0.5	1.0[a]	—		**R1784**

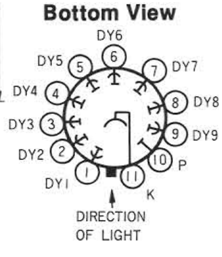
(G) Sockets may be available from electronics supply houses or our sales offices.
(H) The maximum ambient temperature range is −80 to +50°C. When using a tube with glass base at −30°C or below, see precautions on page 74.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).
a : At 2000 Vdc

Unit: mm

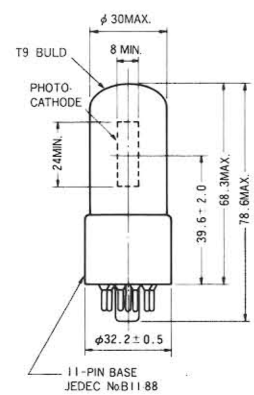
③ R2693

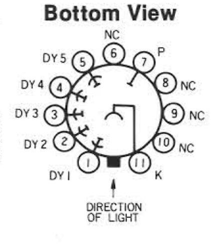






④ R1784





Side-On Type Photomultiplier Tubes

Type No. Ⓐ	Remarks	Spectral Response: Curve Code Ⓑ	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material Ⓒ	Window Material Ⓓ	Outline No. Ⓔ	Dynode Structure / No. of Stages Ⓕ	Socket Ⓖ	Maximum Ratings Ⓗ: Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓗ: Average Anode Current Ⓙ (mA)	Cathode Sensitivity, Luminous: Min. (μA/lm)	Cathode Sensitivity, Luminous: Typ. (μA/lm)
1-1/8 inch (28 mm) Dia. Types with UV to Near IR Sensitivity													
*R2368	Semitransparent photocathode, excellent uniformity	500U	185~850	420	M	U	1	CC/9	E678-11A	1250	0.1	80	150
R777	Multialkali photocathode with peak at 400 nm	555U	185~850	400	M	U	2	CC/9	E678-11A	1250	0.1	140	170
R446	Multialkali photocathode with peak at 330 nm	551U	185~870	330	M	U	2	CC/9	E678-11A	1250	0.1	50	80
*R508	General purpose type of R446 with less red sensitivity	559U	185~810	330	M	U	2	CC/9	E678-11A	1250	0.1	20	45
R456	Variant of R446 with synthetic silica window	551S	160~870	330	M	Q	2	CC/9	E678-11A	1250	0.1	50	80
R928	Extended red, high sensitivity multialkali photocathode	552U	185~900	400	M	U	2	CC/9	E678-11A	1250	0.1	140	200
R955	Variant of R928 with synthetic silica window	552S	160~900	400	M	Q	2	CC/9	E678-11A	1250	0.1	140	200
R1477	High sensitivity variant of R928 with peak at 450 nm	554U	185~900	450	M	U	2	CC/9	E678-11A	1250	0.1	350	375
R936	Extended red sensitivity to 930 nm	556U	185~930	420	M	U	2	CC/9	E678-11A	1250	0.1	30	70
R1913	5-stage, high pulse linearity fast time response	557U	185~900	420	M	U	4	CC/5	E678-11A	2000	0.1	—	200
R636	GaAs photocathode with high QE and wide, flat response	650U	185~930	300~800	GaAs(Cs)	U	3	CC/9	E678-11A	1500	0.001	300	450
R666	High gain variant of R636	651U	185~910	350	GaAs(Cs)	U	3	CC/9	E678-11A	1250	0.01	80	150
R666S	Variant of R666 with high QE				GaAs(Cs)	U	3	CC/9	E678-11A	1250	0.01	200	250
*R2658	High S/N in the range of 900~1000 nm	850U	185~1010	400	I G A	U	3	CC/9	E678-11A	1500	0.001	—	100
R406	For red to IR detection, near S-1 response	750K	400~1100	730	Ag-O-Cs	K	2	CC/9	E678-11A	1500	0.01	10	20

Ⓐ * : Newly listed in this catalog.

Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.

Ⓒ Photocathode materials
- M : Multialkali
- I G A : InGaAs (Cs)

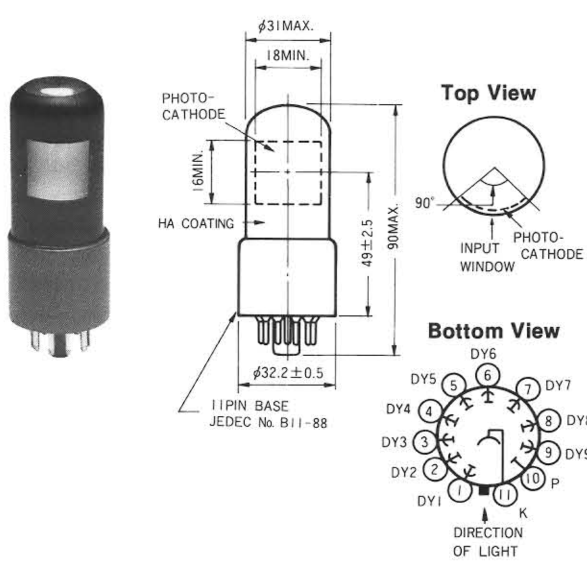
Ⓓ Window materials
- U : UV glass
- Q : Synthetic silica
- K : Borosilicate glass

Ⓔ Basing diagram symbols are explained on page 17.

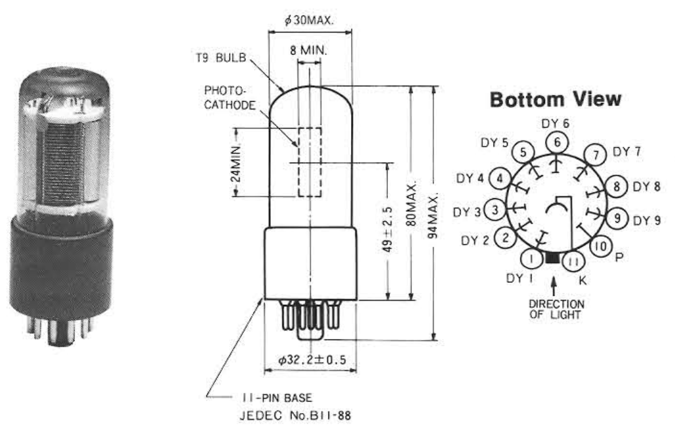
Ⓕ Dynode Structure
- CC : Circular-cage

Ⓖ Sockets may be available from electronics supply houses or our sales offices.

1 R2368



2 R777, R446, R928 etc.



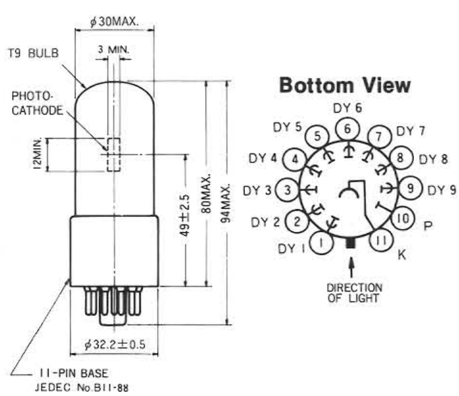
(at 25°C)

Cathode Sensitivity			Anode to Cathode Supply Voltage (L)	Anode Characteristics (M)								Notes	Type No. (A)
				Anode Sensitivity			Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response			
				Luminous		Radiant Typ. (K)							
Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Radiant Typ. (K) (mA/W)	(Vdc)	Min. (A/lm)	Typ. (A/lm)	(A/W)		Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)		
—	0.15	—	1000 (10)	50	200	—	1.3×10^6	5	50	1.2	18		R2368 *
5.5	0.15	65	1000 (10)	300	700	2.7×10^5	4.1×10^6	2	50	2.2	22	Silica window type (R787) available.	R777
4.0	0.25	40	1000 (10)	100	400	2.0×10^5	5.0×10^6	2	50	2.2	22		R446
3.0	0.1	30	1000 (10)	40	100	8.8×10^4	2.2×10^6	2	50	2.2	22		R508 *
4.5	0.25	40	1000 (10)	100	400	2.0×10^5	5.0×10^6	2	50	2.2	22		R456
7.5	0.3	68	1000 (10)	400	2000	6.8×10^5	1.0×10^7	2	50	2.2	22	Photn counting type (R2949) available.	R928
7.5	0.3	68	1000 (10)	400	2000	6.8×10^5	1.0×10^7	2	50	2.2	22		R955
10.0	0.35	80	1000 (10)	1000	2000	4.2×10^5	5.3×10^6	2	50	2.2	22		R1477
—	0.4	30	1000 (10)	50	300	1.3×10^5	4.3×10^6	2	50	2.2	22		R936
7.5	—	65	600 (2)	—	0.6	—	3.0×10^3	0.05	0.5	1.0[c]	—		R1913
8.0	0.53	62	1250 (10)	20	80	1.1×10^4	1.8×10^5	0.1[d]	2[d]	2.0	20	Silica window type (R758) available.	R636
4.0	0.43	35	1000 (10)	100	300	7.0×10^4	2.0×10^6	15	50	2.2	22	Silica window type (R764) available.	R666
5.5	0.45	48	1000 (10)	100	300	5.8×10^4	1.2×10^6	15	50	2.2	22		R666S
—	0.38	40	1250 (10)	—	16	6.4×10^3	1.6×10^5	1	10	2.0	20		R2658 *
5.5	0.05[b]	1.9	1250 (10)	1	4	380	2.0×10^5	30[a]	100[a]	2.0	20		R406

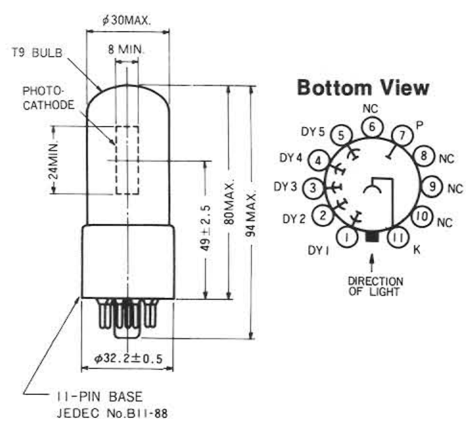
(H) The maximum ambient temperature range is −80 to +50°C.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).
a : At 4A/lm
b : Measured using a red filter Toshiba IR-D80A.
c : At 2000 Vdc.
d : At 10A/lm

Unit: mm

(3) R636, R666, R2658 etc.



(4) R1913

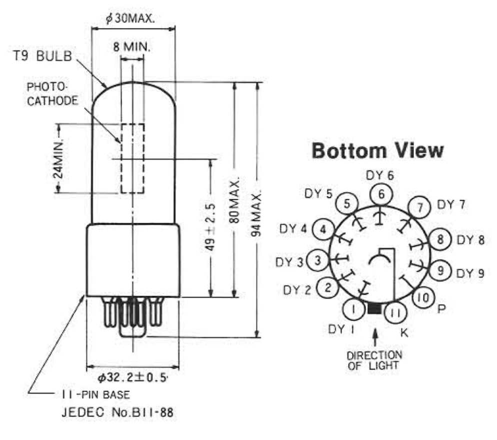


Side-On and Dormer Window Type Photomultiplier Tubes

Ⓐ Type No.	Remarks	Spectral Response: Ⓑ Curve Code	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Ⓒ Photocathode Material	Ⓓ Window Material	Ⓔ Outline No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket	Maximum Ratings Ⓗ: Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓗ: Ⓙ Average Anode Current (mA)	Cathode Sensitivity Luminous: Min. (µA/lm)	Cathode Sensitivity Luminous: Typ. (µA/lm)
1-1/8 inch (28 mm) Dia. Side-On Types with Solar Blind Response													
R1259	Solar blind response, Cs-I photocathode, MgF_2 window	150M	115~195	120	Cs-I	MF	❷	CC/9	E678-11A■	1250	0.1	—	—
R166	Solar blind response, Cs-Te photocathode, synthetic silica	250S	160~320	200	Cs-Te	Q	❶	CC/9	E678-11A■	1250	0.1	—	—
R166UH	High gain variant of R166	250S	160~320	200	Cs-Te	Q	❶	CC/9	E678-11A■	1250	0.1	—	—
R1220	Variant of R166 with projected MgF_2 window	250M	115~320	190	Cs-Te	MF	❷	CC/9	E678-11A■	1250	0.1	—	—
1-1/2 inch (38 mm) Dia. Dormer Window Types													
*R2752	Bialkali photocathode, temporary base	457U	300~680	450	Bi	K	❸	CC/10	E678-12A★	1500	0.1	100	140
R1923	Multialkali photocathode, temporary base	558K	300~800	530	M	K	❸	CC/10	E678-12A★	2000	0.1	200	300

Ⓐ *: Newly listed in this catalog.
Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓒ Photocathode Materials
  Bi : Bialkali
  M : Multialkali
Ⓓ Window Materials
  MF : MgF_2
  Q : Synthetic silica
  K : Borosilicate glass
Ⓔ Basing diagram symbols are explained on page 17.
Ⓕ Dynode Structure
  CC : Circular-cage
Ⓖ ★ : A socket will be supplied with a tube.
  ■ : Sockets may be available from electronics supply houses or our sales offices.
Ⓗ The maximum ambient temperature range is −80 to +50°C.
Ⓙ Averaged over any interval of 30 seconds maximum.
Ⓚ At the wavelength of peak response.
Ⓛ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓜ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓛ.
a : At 122 nm
b : At 254 nm

❶ R166, R166UH

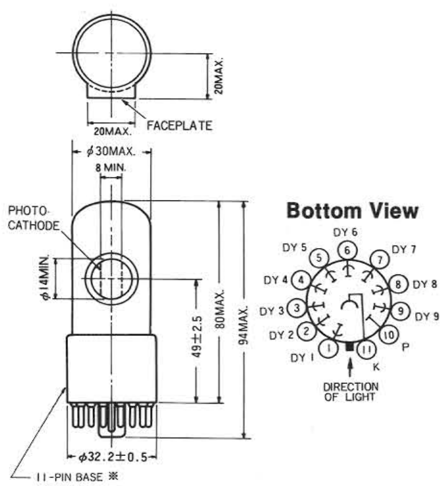


(at 25°C)

Cathode Sensitivity: Blue Typ. (µA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Ⓚ Radiant Typ. (mA/W)	Ⓛ Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics Ⓜ: Anode Sensitivity: Luminous Min. (A/lm)	Anode Sensitivity: Luminous Typ. (A/lm)	Anode Sensitivity: Ⓚ Radiant Typ. (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Ⓐ Type No.
—	—	26[a]	1000 ⑩	—	—	3.1×10^{4}[a]	1.2×10^{6}	1	1.0	2.2	22		**R1259**
—	—	40[b]	1000 ⑩	—	—	1.0×10^{5}[b]	2.5×10^{6}	0.1	0.5	2.2	22	Sharp cutoff solar blind type (R1356) available.	**R166**
—	—	40[b]	1000 ⑩	—	—	4.0×10^{5}[b]	1.0×10^{7}	1	50	2.2	22		**R166UH**
—	—	31[b]	1000 ⑩	—	—	5.7×10^{4}[b]	1.8×10^{6}	1	50	2.2	22		**R1220**
14.0	—	100	1250 ⑭	—	35	2.5×10^{4}	2.5×10^{5}	1	10	2.2	22	Replaceable with RCA 4526.	**R2752** *
8.0	0.12	89	1250 ⑭	5	15	4.4×10^{3}	5.0×10^{4}	1	10	2.2	22	Direct replacement for RCA 4526.	**R1923**

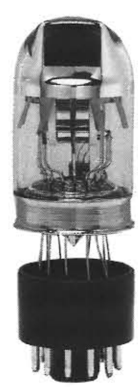
Unit: mm

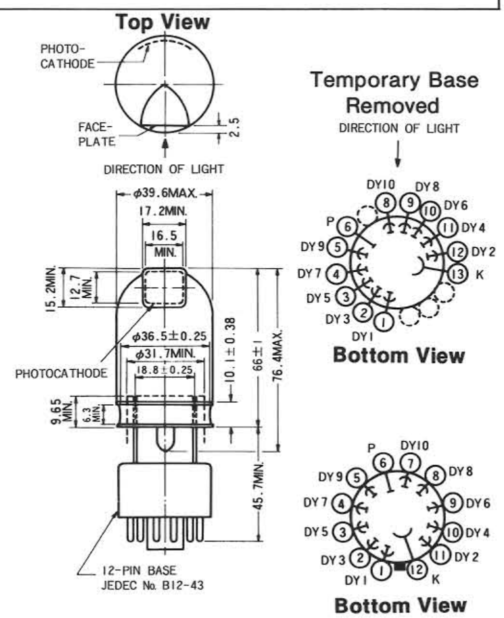
❷ R1259, R1220



※Since the R1259 and R1220 are often used in vacuum, the base has a samll hole for air flow to maintain the same pressure level as the outside of the base.

❸ R1923, R2752



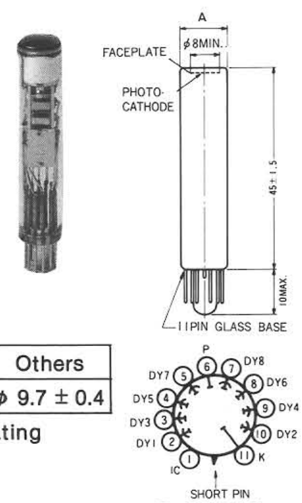


Head-On Type Photomultiplier Tubes

Ⓐ Type No.	Remarks	Spectral Response Ⓑ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wave-length (nm)	Ⓒ Photo-cathode Material	Ⓓ Window Material	Ⓔ Out-line No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket	Maximum Ratings Ⓗ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓙ Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
3/8 inch (10 mm) Dia. Types													
R1893	Solar blind response, Cs-Te photocathode, synthetic silica	200S	160~320	210	Cs-Te	Q	❶	L/8	E678-11N	1500	0.01	—	—
R1635	Visible response, bialkali photocathode	400K	300~650	420	Bi	K	❶	L/8	E678-11N	1500	0.03	60	90
R1635-02	For photon counting, HA coating with magnetic shield				Bi	K	❶	L/8	E678-11N	1500	0.03	60	90
R1894	S-20 response, multialkali photocathode	500K (S-20)	300~850	420	M	K	❶	L/8	E678-11N	1500	0.03	80	120
*R2496	Low TTS, high speed time response	400S	160~650	420	Bi	Q	❷	L/8	E678-11N	1500	0.03	60	90
1/2 inch (13 mm) Dia. Types													
R1081	For VUV detection, MgF_2 window, temporary base	100M	115~200	140	Cs-I	MF	❺	L/10	E678-12A	2250	0.01	—	—
R1080	Variant of R1081 with Cs-Te photocathode	200M	115~320	210	Cs-Te	MF	❺	L/10	E678-12A	1250	0.01	—	—
R759	Solar blind response, Cs-Te photocathode, synthetic silica	200S	160~320	210	Cs-Te	Q	❸	L/10	E678-13A	1250	0.01	—	—
R647	10-stage, bialkali photocathode	400K	300~650	420	Bi	K	❸	L/10	E678-13A	1250	0.1	40	80
R647-01	Selected for scintillation counting				Bi	K	❸	L/10	E678-13A	1250	0.1	60	90
R647-04	For photon counting, HA Coating with magnetic shield				Bi	K	❹	L/10	E678-13A	1250	0.1	60	90
R760	Variant of R647 with synthetic silica window	400S	160~650	420	Bi	Q	❸	L/10	E678-13A	1250	0.1	40	90
R1591-01	High temp. bialkali photo-cathode, ruggedized type	401K	300~650	375	H Bi	K	❸	L/10	E678-13E	1800	0.1	—	40
R1463	High gain variant of R761	500U	185~850	420	M	U	❸	L/10	E678-13A	1250	0.03	80	120
R1463-01	For photon counting, HA Coating with magnetic shield				M	U	❹	L/10	E678-13A	1250	0.03	80	120

Ⓐ * : Newly listed in this catalog.
Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓒ Photocathode materials
  Bi : Bialkali
  M : Multialkali
  H Bi : High temperature bialkali
Ⓓ Window materials
  Q : Synthetic silica
  K : Borosilicate glass
  MF : MgF_2
  U : UV glass
Ⓔ Basing diagram symbols are explained on page 17.
Ⓕ Dynode Structure
  L : Linear focused
Ⓖ A socket will be supplied with a tube.
Ⓗ The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
Ⓙ Averaged over any interval of 30 seconds maximum.
Ⓚ At the wavelength of peak response.
Ⓛ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓜ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓛ.
a : At 122 nm
b : At 254 nm
c : Dark counts per second (cps)

❶ R1893, R1635 etc.

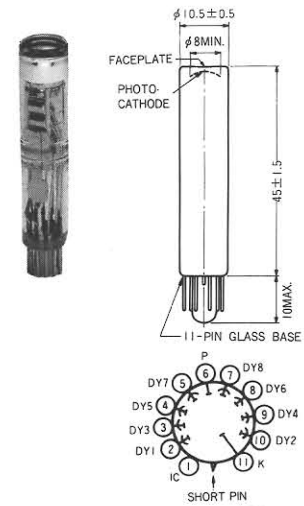


Bottom View

	R1635-02	R1893	Others
A	φ 11.0 ± 0.5	φ 10.5 ± 0.5	φ 9.7 ± 0.4

※ R1635-02 has an HA coating with magnetic shield.

❷ R2496



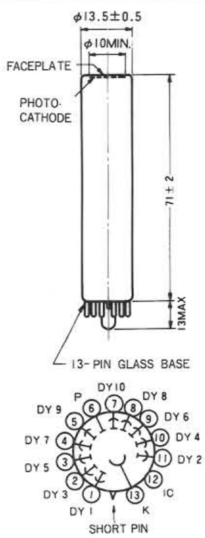
Bottom View

(at 25°C)

Cathode Sensitivity			Anode to Cathode Supply Voltage (L)	Anode Characteristics (M)								Notes	Type No. (A)
				Anode Sensitivity			Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response			
				Luminous		Radiant (K) Typ.				Rise Time Typ.	Electron Transit Time Typ.		
Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Radiant (K) Typ. (mA/W)	(Vdc)	Min. (A/lm)	Typ. (A/lm)	(A/W)		Typ. (nA)	Max. (nA)	(ns)	(ns)		
—	—	12^b	1250 (5)	—	—	3600^b	3.0×10^5	0.5	2.5	0.8	7.8		R1893
10.5	—	82	1250 (5)	30	90	8.2×10^4	1.0×10^6	5.0	50	0.8	7.8	Silica window type (R2055) available.	R1635
10.5	—	82	1250 (5)	50	200	1.8×10^5	2.2×10^6	100^c cps	400^c cps	0.8	7.8		R1635-02
—	0.2	51	1250 (5)	10	50	2.1×10^4	4.2×10^5	2.0	20	0.8	7.8		R1894
10.5	—	82	1250 (8)	30	90	8.2×10^4	1.0×10^6	5.0	50	0.7	7.8		R2496*
—	—	9.8^a	2000 (11)	—	—	980^a	1.0×10^5	0.03	0.05	1.8	18		R1081
—	—	20^b	1000 (11)	—	—	2.0×10^{4b}	1.0×10^6	0.3	0.5	2.5	24		R1080
—	—	20^b	1000 (11)	—	—	1.0×10^{4b}	5.0×10^5	0.3	1.0	2.5	24		R759
9.5	—	75	1000 (11)	30	80	7.5×10^4	1.0×10^6	5.0	15	2.5	24	UV glass window type (R960) available.	R647
10.5	—	80	1000 (11)	30	90	8.0×10^4	1.0×10^6	1.0	2.0	2.5	24		R647-01
10.5	—	80	1000 (11)	70	200	1.8×10^5	2.2×10^6	80^c cps	400^c cps	2.5	24		R647-04
10.5	—	80	1000 (11)	10	90	8.0×10^4	1.0×10^6	5.0	15	2.5	24		R760
6.0	—	50	1500 (11)	10	20	2.5×10^4	5.0×10^5	0.5	10	2.0	20	Flexible lead type (R1591) available.	R1591-01
—	0.2	51	1000 (11)	30	120	5.1×10^4	1.0×10^6	4.0	20	2.5	24	HV resistant type (R761) and silica window type (R2007) available.	R1463
—	0.2	51	1000 (11)	30	120	5.1×10^4	1.0×10^6	900^c cps	1000^c cps	2.5	24		R1463-01

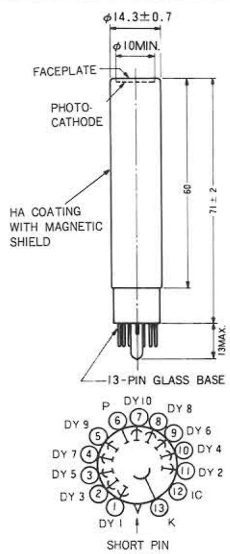
Unit: mm

(3) R647, R760 etc.



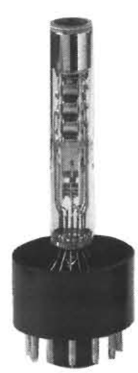
Bottom View

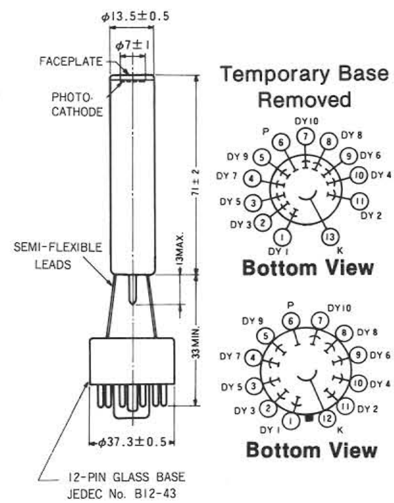
(4) R647-04, R1463-01



Bottom View

(5) R1080, R1081





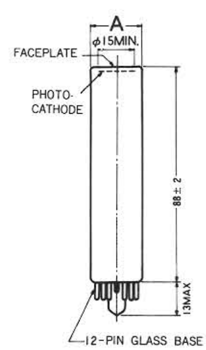
Bottom View

Head-On Type Photomultiplier Tubes

Type No. Ⓐ	Remarks	Spectral Response: Curve Code Ⓑ	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material Ⓒ	Window Material Ⓓ	Outline No. Ⓔ	Dynode Structure / No. of Stages Ⓕ	Socket Ⓖ	Maximum Ratings Ⓗ: Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓗ: Average Anode Current (mA) Ⓙ	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
3/4 inch (19 mm) Dia. Types													
R972	For VUV detection, MgF_2 window, temporary base	100M	115~200	140	Cs-I	M·F	❸	L/10	E678-12A	2250	0.01	—	—
R821	Solar blind response, Cs-Te photocathode, synthetic silica	200S	160~320	210	Cs-Te	Q	❶	L/10	E678-12D	1250	0.01	—	—
R1213	For scintillation counting, 10-stage, bialkali	400K	300~650	420	Bi	K	❶	L/10	E678-12D	1800	0.1	70	90
R1166	High gain variant of R1213				Bi	K	❶	L/10	E678-12D	1250	0.1	70	90
R1450	For scintillation counting, small TTS				Bi	K	❶	L/10	E678-12D	1800	0.1	70	100
R750	High gain variant of R654	400U	185~650	420	Bi	U	❶	L/10	E678-12D	1250	0.1	40	90
R2076	For positron CT using BaF_2, 8-stage	400S	160~650	420	Bi	Q	❷	L/8	E678-12D	1800	0.1	60	100
R1281	High temp. bialkali photocathode, ruggedized type	401K	300~650	375	H Bi	K	❹	L/10	E678-12A	1800	0.1	—	40
R1617	S-20 response, multialkali photocathode	500K (S-20)	300~850	420	M	K	❶	L/10	E678-12D	1250	0.1	80	120
* R2027	Variant of R1617 with synthetic silica window	500S	165~850	420	M	Q	❶	L/10	E678-12D	1250	0.1	80	120
R1464	Variant of R1617 with UV glass window	500U	185~850	420	M	U	❶	L/10	E678-12D	1250	0.1	80	120
R632	For red to IR detection, S-1 response	700K	400~1200	800	Ag-O-Cs	K	❶	L/10	E678-12D	1500	0.01	10	20
R632-01	High red-sensitivity variant of R632, QE 0.08% at 1.06μm				Ag-O-Cs	K	❶	L/10	E678-12D	1500	0.01	10	20

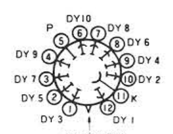
Ⓐ *: Newly listed in this catalog.
Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓒ Photocathode materials
  Bi : Bialkali
  H Bi : High temperature bialkali
  M : Multialkali
Ⓓ Window materials
  MF : MgF_2
  K : Borosilicate glss
  U : UV glass
  Q : Synthetic silica
Ⓔ Basing diagram symbols are explained on page 17.
Ⓕ Dynode Structure
  L : Linear focused
Ⓖ A socket will be supplied with a tube.
Ⓗ The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
Ⓙ Averaged over any interval of 30 seconds maximum.
Ⓚ At the wavelength of peak response.
Ⓛ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓜ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓛ.
a : At 122 nm
b : At 254 nm
c : Measured using a red filter Toshiba IR-D80A.
d : At 4A/lm

❶ R1213, R1450 etc.



	R762 R763 R821	Others
A	φ 19 ± 1	φ 18.6 ± 0.7

R1450 has a plano-concave faceplate.



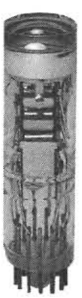
Bottom View

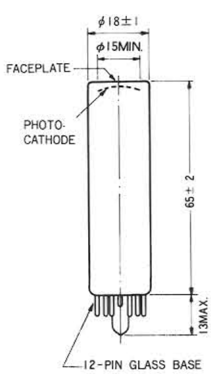
(at 25°C)

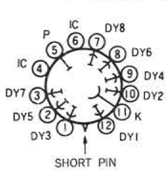
Cathode Sensitivity			Anode to Cathode Supply Voltage Ⓛ	Anode Characteristics Ⓜ								Notes	Type No. Ⓐ
Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Radiant Typ. Ⓚ (mA/W)	(Vdc)	Anode Sensitivity: Luminous Min. (A/lm)	Anode Sensitivity: Luminous Typ. (A/lm)	Anode Sensitivity: Radiant Typ. Ⓚ (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)		
—	—	9.8[a]	2000 ⑬	—	—	980[a]	1.0×10^5	0.03	0.05	1.6	17		**R972**
—	—	20[b]	1000 ⑬	—	—	1.0×10^4[b]	5.0×10^5	0.3	0.5	2.5	27	MgF_2 window type (R976) available.	**R821**
11.0	—	85	1500 ⑬	10	60	5.7×10^4	6.7×10^5	10	50	1.9	21		**R1213**
11.0	—	85	1000 ⑬	10	70	6.6×10^4	7.8×10^5	1.0	5	2.5	27		**R1166**
11.5	—	90	1500 ⑮	100	200	1.8×10^5	2.0×10^6	10	50	1.8	19		**R1450**
11.0	—	85	1000 ⑬	10	70	6.6×10^4	7.8×10^5	1.0	5	2.5	27	Silica window type (R762) available.	**R750**
11.5	—	90	1700 ⑨	50	200	1.8×10^5	2.0×10^6	30	300	1.3	14		**R2076**
6.0	—	50	1500 ⑬	20	50	6.5×10^4	1.3×10^6	0.5	10	1.9	21	Glass base type (R1281-02) available.	**R1281**
—	0.2	51	1000 ⑬	30	120	5.1×10^4	1.0×10^6	4.0	20	2.5	27		**R1617**
—	0.2	51	1000 ⑬	30	120	5.1×10^4	1.0×10^6	4.0	20	2.5	27		**R2027** *
—	0.2	51	1000 ⑬	30	120	5.1×10^4	1.0×10^6	4.0	20	2.5	27	HV resistant type (R663) available.	**R1464**
—	0.1[c]	1.9	1250 ⑬	5	10	950	5.0×10^5	100[d]	500[d]	2.2	25	HV resistant type (R763) available.	**R632**
—	0.14[c]	1.9	1250 ⑬	5	10	950	5.0×10^5	300[d]	2000[d]	2.2	25		**R632-01**

Unit: mm

❷ R2076

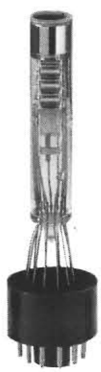




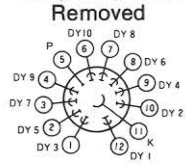


Bottom View

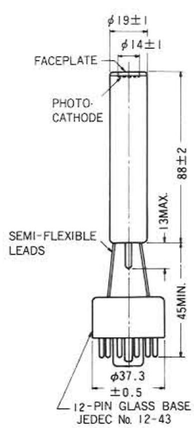
❸ R972

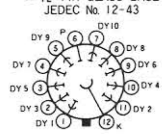


Temporary Base Removed



Bottom View

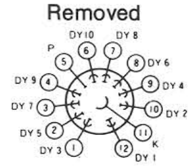




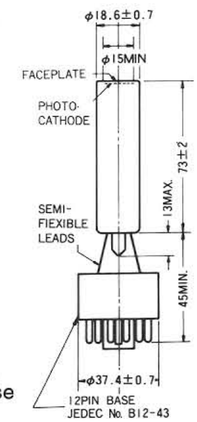
Bottom View

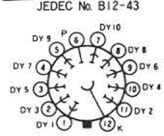
❹ R1281

Temporary Base Removed



Bottom View





Bottom View

Head-On Type Photomultiplier Tubes

Type No.	Remarks	Spectral Response: Curve Code (A)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (B)	Window Material (C)	Outline No. (D)	Dynode Structure / No. of Stages (E)	Socket (F)	Maximum Ratings (G): Anode to Cathode Voltage (Vdc)	Maximum Ratings (G): Average Anode Current (mA) (H)	Cathode Sensitivity, Luminous: Min. (μA/lm)	Cathode Sensitivity, Luminous: Typ. (μA/lm)
1 inch (25 mm) Dia. Types													
R1535	For scintillation counting, 10-stage, bialkali	400K	300~650	420	Bi	K	1	L/10	E678-14C	1800	0.2	60	90
1 inch (25 mm) Dia. Low Profile Types													
R2078	Enhanced solar blind spectral response	201S	160~320	240	Cs-Te	Q	2	CC/10	E678-12A	2000	0.01	—	—
R1924	Visible spectral response bialkali photocathode	400K	300~650	420	Bi	K	3	CC/10	E678-14C	1250	0.1	60	90
R1288	High temp. bialikali photocathode, ruggedized type	401K	300~650	375	H Bi	K	2	CC/10	E678-12A	1800	0.1	—	40
R1925	S-20 response, multialkali photocathode	500K (S-20)	300~850	420	M	K	3	CC/10	E678-14C	1250	0.1	80	120

(A) Typical spectral response characteristics are shown on pages 76 and 77.

(B) Photocathode materials
- Bi : Bialkali
- H Bi : High temperature bialkali
- M : Multialkali

(C) Window materials
- K : Borosilicate glass
- Q : Synthetic silica

(D) Basing diagram symbols are explained on page 17.

(E) Dynode Structure
- L : Linear focused
- CC : Circular-cage

(F) A socket will be supplied with a tube.

(G) The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.

(H) Averaged over any interval of 30 seconds maximum.

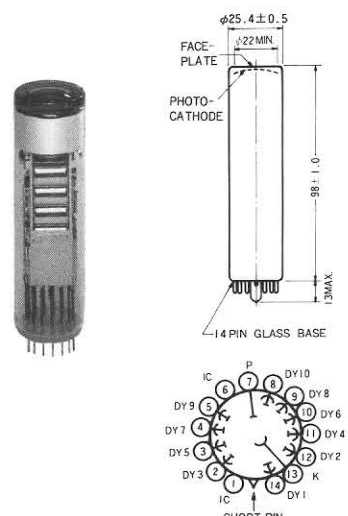
(J) At the wavelength of peak response.

(K) Voltage distribution ratios used to measure characteristics are shown on page 62.

(L) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (K).

a : At 254 nm

1 R1535



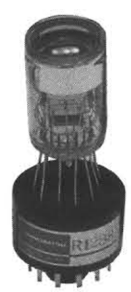
Bottom View

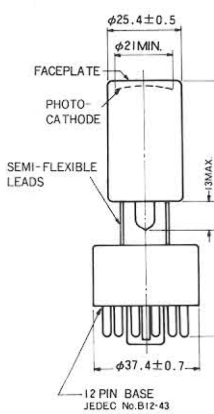
(at 25°C)

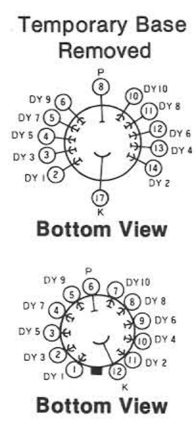
Cathode Sensitivity: Blue Typ. (μA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (mA/W) Ⓙ	Anode to Cathode Supply Voltage (Vdc) Ⓚ	Anode Characteristics Ⓛ: Anode Sensitivity, Luminous Min. (A/lm)	Anode Sensitivity, Luminous Typ. (A/lm)	Anode Sensitivity, Radiant Typ. (A/W) Ⓙ	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No.
11.0	—	85	1500 ⑱	50	300	2.8×10^5	3.3×10^6	10	100	2.4	22		R1535
—	—	29[a]	1500 ⑰	—	—	1.5×10^4[a]	5.0×10^5	0.015	0.1	1.5	14		R2078
10.5	—	85	1000 ⑰	20	100	9.3×10^4	1.1×10^6	3.0	20	2.0	19		R1924
6.0	—	50	1500 ⑰	8	15	1.9×10^4	3.8×10^5	0.1	10	1.5	14	Glass base type (R1288-01) available.	R1288
—	0.2	51	1000 ⑰	10	30	1.3×10^4	2.5×10^5	3.0	20	2.0	19	Silica window type (R1926) available.	R1925

Unit: mm

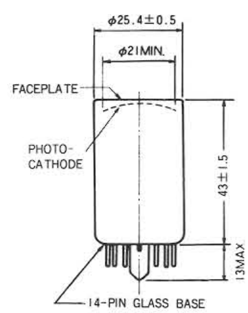
❷ R2078, R1288

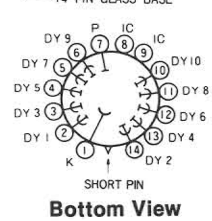






❸ R1924, R1925





Head-On Type Photomultiplier Tubes

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity, Luminous: Min. (µA/lm)	Cathode Sensitivity, Luminous: Typ. (µA/lm)
1-1/8 inch (28 mm) Dia. Types													
R1459	For VUV detection, MgF_2 window, Cs-I Photocathode	100M	115~200	140	Cs-I	MF	1	B/11	E678-14C	2500	0.01	—	—
R1460	Variant of R1459 with Cs-Te photocathode	200M	115~320	210	Cs-Te	MF	1	B/11	E678-14C	1500	0.01	—	—
R431S	Solar blind response, Cs-Te photocathode, short length	200S	160~320	210	Cs-Te	Q	2	B/11	E678-14C	1500	0.01	—	—
R268	Bialkali photocathode, visible response, 11-stage	400K	300~650	420	Bi	K	1	B/11	E678-14C	1500	0.01	60	95
R434	For scintillation counting, 9-stage				Bi	K	4	B/9	E678-14C	1250	0.1	50	95
R1759	Variant of R434 with 7-stage dynodes				Bi	K	4	B/7	E678-14C	1250	0.1	50	95
*R3082	For high energy physics, high speed response, low TTS			420	Bi	K	3	L/10	E678-14C	1500	0.2	60	95
R269	Variant of R268 with UV glass window	400U	185~650	420	Bi	U	1	B/11	E678-14C	1500	0.1	40	95
R292	Variant of R268 with synthetic silica window	400S	160~650	420	Bi	Q	1	B/11	E678-14C	1500	0.1	40	95
*R3172	For high energy physics, high speed response, low TTS				Bi	Q	3	L/10	E678-14C	1500	0.2	60	95
R1282	High temp. bialkali photocathode, ruggedized type	401K	300~650	375	H Bi	K	2	B/11	E678-14H	2500	0.1	—	40
R374	Wide spectral response, multialkali photocathode	500U	185~850	420	M	U	1	B/11	E678-14C	1500	0.1	80	150
R1104	High gain variant of R374				M	U	1	B/11	E678-14C	1500	0.1	80	140
R453	General purpose type of R374 with relaxed dark spec				M	U	1	B/11	E678-14C	1500	0.1	80	120
R376	Variant of R374 with synthetic silica window	500S	160~850	420	M	Q	1	B/11	E678-14C	1500	0.1	80	150
*R2228	Extended red multialkali photocathode	501K	300~900	650	M	K	1	B/11	E678-14C	1500	0.1	100	200
R316	For red to IR detection, S-1 response	700K (S-1)	400~1200	800	Ag-O-Cs	K	1	B/11	E678-14C	1500	0.01	10	20
R316-02	High red-sensitivity variant of R316, QE 0.08% at 1.06µm				Ag-O-Cs	K	1	B/11	E678-14C	1500	0.01	10	20

(A) *: Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on pages 76 and 77.
(C) Photocathode materials
- Bi : Bialkali
- H Bi : High temperature bialkali
- M : Multialkali

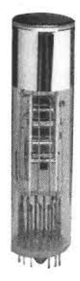
(D) Window materials
- MF : MgF_2
- Q : Synthetic silica
- K : Borosilicate glass
- U : UV glass

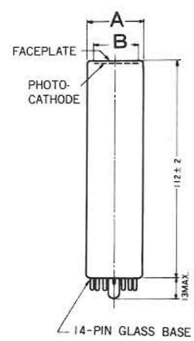
(E) Basing diagram symbols are explained on page 17.
(F) Dynode Structure
- B : Box-and-grid
- L : Linear focused

(G) A socket will be supplied with a tube.
(H) The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).

a : At 122 nm
b : At 254 nm
c : At 1000 A/lm
d : Measured using a red filter Toshiba IR-D80A.
e : At 4 A/lm

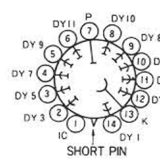
1 R1459, R268 etc.





	MgF_2 and Silica bulb	Others
A	$\phi 28.2 \pm 0.8$	$\phi 28.5 \pm 0.5$
B	ϕ23 mm MIN.	ϕ25 mm MIN.

R2228 has a plano-concave faceplate.



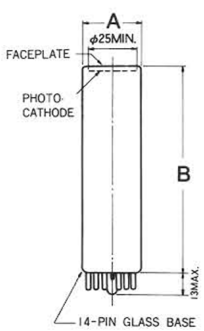
Bottom View

(at 25°C)

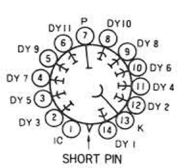
Cathode Sensitivity: Blue Typ. (μA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (K) (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
—	—	9.8[a]	2000 (22)	—	—	980[a]	1.0×10^5	0.03	0.05	9	40		R1459
—	—	20[b]	1000 (22)	—	—	1.0×10^4[b]	5.0×10^5	0.3	0.5	12	60		R1460
—	—	20[b]	1000 (22)	—	—	1.0×10^4[b]	5.0×10^5	0.3	1	12	60		R431S
11.0	—	85	1000 (22)	50	200	1.8×10^5	2.1×10^6	2	10	12	60		R268
11.0	—	85	1000 (10)	10	60	5.4×10^4	6.3×10^5	1	5	12	76	Multialkali type (R1594) available.	R434
11.0	—	85	800 (4)	0.5	3	2.7×10^3	3.2×10^4	0.2	2	10	—		R1759
11.0	—	85	1250 (20)	50	200	1.8×10^5	2.1×10^6	5	100	2.2	26	Direct replacement for R1398 (UV glass window).	R3082*
11.0	—	85	1000 (22)	50	200	1.8×10^5	2.1×10^6	2	10	12	60		R269
11.0	—	85	1000 (22)	50	200	1.8×10^5	2.1×10^6	2	10	12	60		R292
11.0	—	85	1250 (21)	20	80	7.1×10^4	8.4×10^5	5	100	2.2	29	Direct replacement for R1668 (HV resistant type).	R3172*
6.0	—	50	2000 (22)	200	400	5.0×10^5	1.0×10^7	5	100	9	40		R1282
—	0.2	64	1000 (22)	20	80	3.4×10^4	5.3×10^5	3	15	15	60		R374
—	0.2	60	1000 (22)	500	2000	8.4×10^5	1.4×10^7	20[c]	50[c]	15	60		R1104
—	0.1	51	1000 (22)	20	80	3.4×10^4	6.7×10^5	10	50	15	60		R453
—	0.2	64	1000 (22)	20	80	3.4×10^4	5.3×10^5	3	15	15	60	General purpose type (R457) available.	R376
—	0.3	40	1000 (22)	20	150	3.0×10^4	7.5×10^5	8	30	15	60	Direct replacement for R712 (UV glass window).	R2228*
—	0.1[d]	1.9	1250 (22)	5	10	950	5.0×10^5	1000[e]	3000[e]	10	50		R316
—	0.14[d]	1.9	1250 (22)	5	10	950	5.0×10^5	1500[e]	5000[e]	10	50		R316-02

Unit: mm

② R431S, R1282

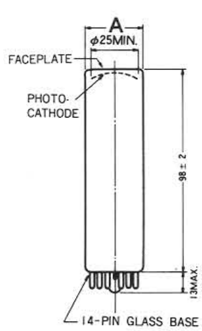


	R431S	R1282
A	φ28.2 ± 0.8	φ28.5 ± 0.5
B	92 ± 2	97 ± 2

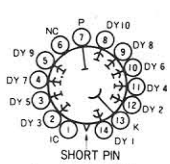


Bottom View

③ R3082,R3172

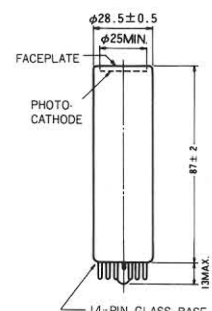


	R3172	R3082
A	φ28.5 ± 0.8	φ28.5 ± 0.5

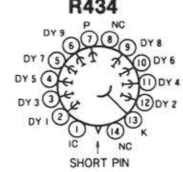


Bottom View

④ R434, R1759

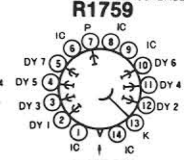


R434



Bottom View

R1759



Bottom View

Head-On Type Photomultiplier Tubes

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
1-1/8 inch (28 mm) Dia. Short Bulb Types with 4-Stage Dynode													
R546	4-stage, short length, bialkali photocathode	400K	300 ~ 650	420	Bi	K	1	B/4	E678-11C	1000	0.005	40	80
R567	Variant of R546 with multialkali photocathode, UV glass	500U	185 ~ 850	420	M	U	1	B/4	E678-11C	1000	0.005	80	150
R568	Variant of R546 with S-1 response	700K (S-1)	400 ~ 1200	800	Ag-O-Cs	K	1	B/4	E678-11C	1000	0.005	10	20
R568-01	High red-sensitivity variant of R568, QE 0.08% at 1.06μm				Ag-O-Cs	K	1	B/4	E678-11C	1000	0.005	10	20
1-3/8 inch (34 mm) Dia. Stacked Ceramic-to-Metal Sealed, Ruggedized Type													
R1689-02	Solar blind response, ruggedized type	201A	150 ~ 320	240	Cs-Te	S	2	VB/13	—	3000	0.005	—	—
*R1317-05	High temperature ruggedized type	401K	300 ~ 650	375	H Bi	K	2	VB/12	—	3000	0.01	—	40
1-1/2 inch (38 mm) Dia. Types													
6199	S-11 response, circular-cage dynodes, general purpose	300K (S-11)	300 ~ 650	440	Sb-Cs	K	3	CC/10	E678-12A	1250	0.1	40	60
R980	For scintillation counting, variant of 6199	400K	300 ~ 650	420	Bi	K	3	CC/10	E678-12A	1250	0.1	70	95
R580	For scintillation counting, fast time response				Bi	K	4	L/10	E678-12A	1600	0.1	70	95
R1387	Variant of 6199 with S-20 response, multialkali	500K (S-20)	300 ~ 850	420	M	K	3	CC/10	E678-12A	1250	0.2	80	150
*R1705	High temperature ruggedized type	401K	300 ~ 650	375	H Bi	K	3	CC/10	E678-12A	1800	0.1	—	40
R2066	Extended red multialkali photocathode	501K	300 ~ 900	650	M	K	3	CC/10	E678-12A	1500	0.2	120	200
7102	For red to IR detection, S-1 response	700K (S-1)	400 ~ 1200	800	Ag-O-Cs	K	3	CC/10	E678-12A	1500	0.01	10	25
R1767	High red-sensitivity of 7102, QE 0.08% at 1.06μm				Ag-O-Cs	K	3	CC/10	E678-12A	1500	0.01	10	25

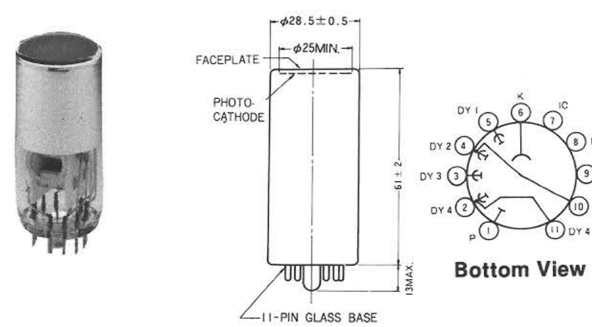
(A) * : Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on pages 76 and 77.
(C) Photocathode materials
- Bi : Bialkali
- M : Multialkali
- H Bi : High temperature bialkali

(D) Window materials
- K : Borosilicate glass
- U : UV glass
- S : Sapphire glass

(E) Basing diagram symbols are explained on page 17.
(F) Dynode Structure
- B : Box-and-grid
- CC : Circular-cage
- L : Linear focused

(G) A socket will be supplied with a tube.
(H) The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).
a : Measured using a red filter Toshiba IR-D80A.
b : At 4 A/lm

1 R546, R567 etc.

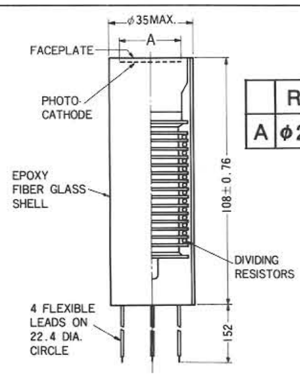


(at 25°C)

Cathode Sensitivity: Blue Typ. (μA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (mA/W) Ⓚ	Anode to Cathode Supply Voltage (Vdc) Ⓛ	Anode Characteristics Ⓜ: Anode Sensitivity, Luminous Min. (A/lm)	Luminous Typ. (A/lm)	Radiant Typ. (A/W) Ⓚ	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response: Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)	Notes	Type No. Ⓐ
10.5	—	80	750 ①	0.025	0.08	80	1000	0.3	1.0	8.7	—		**R546**
—	0.2	64	750 ①	0.025	0.08	34	530	0.3	1.0	8.7	—		**R567**
—	0.1[a]	1.9	750 ①	0.0025	0.01	0.95	500	5	15	8.7	—		**R568**
—	0.14[a]	1.9	750 ①	0.0025	0.01	0.95	500	10	40	8.7	—		**R568-01**
—	—	27	2500	—	—	5.4×10^4	2.0×10^6	0.03	0.5	7.5	—	Voltage divider circuit incorporated.	**R1689-02**
6.0	—	50	2000	5	20	2.5×10^4	5.0×10^5	0.5	10	—	—	Voltage divider circuit incoporated.	**R1317-05***
—	—	47	1000 ⑭	20	100	8.0×10^4	1.7×10^6	3	30	2.8	40		**6199**
11.5	—	90	1000 ⑭	10	35	3.3×10^4	3.7×10^5	1	5	2.8	40	Ruggedized type (R1639), Silica window type (R189) available.	**R980**
11.0	—	85	1250 ⑭	10	35	3.3×10^4	3.7×10^5	2	15	2.7	37		**R580**
—	0.2	64	1000 ⑭	10	50	2.1×10^4	3.3×10^5	4	25	2.8	40	UV glass window type (R1508), Silica window type (R1509) available.	**R1387**
6.0	—	50	1500 ⑭	5	20	2.5×10^4	5.0×10^5	0.5	10	2.0	35		**R1705***
—	0.3	47	1000 ⑭	10	50	1.2×10^4	2.5×10^5	8	30	2.8	40		**R2066**
—	0.1[a]	2.4	1250 ⑭	1	5	480	2.0×10^5	1000[b]	5000[b]	2.2	37		**7102**
—	0.14[a]	2.4	1250 ⑭	1	5	480	2.0×10^5	7000[b]	20000[b]	2.2	37		**R1767**

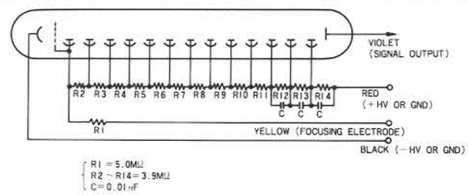
Unit: mm

❷ R1689-02, R1317-05

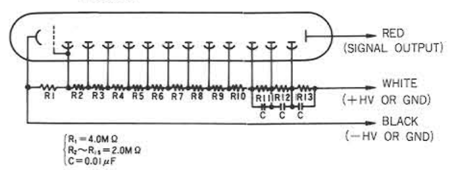


	R1689-02	R1317-05
A	φ25.4MIN.	φ27.0MIN.

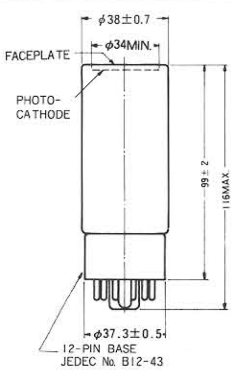
R1689-02

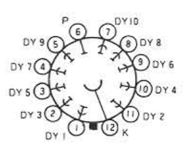


R1317-05



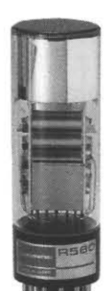
❸ 6199, R980, R1387 etc.

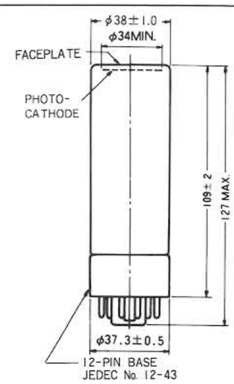


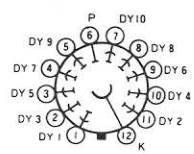


Bottom View

❹ R580







Bottom View

Head-On Type Photomultiplier Tubes

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity Luminous: Min. (μA/lm)	Cathode Sensitivity Luminous: Typ. (μA/lm)
2 inch (51 mm) Dia. Types with Plastic Base													
7696	S-11 response, general purpose	300K (S-11)	300~650	440	Sb-Cs	K	1	B/10	E678-14A■	1500	0.1	40	80
R1306	For scintillation counting, 8-stage				Bi	K	2	B/8	E678-14A■	1500	0.1	80	95
*R1847-07	For scintillation counting, low profile				Bi	K	3	B+M/10	E678-14A■	1500	0.1	80	100
R878	For scintillation counting, 10-stage	400K	300~650	420	Bi	K	1	B/10	E678-14A■	1500	0.1	60	95
R1840	High pulse linearity good immunity to magnetic field				Bi	K	4	M/10	E678-14A■	1500	0.1	40	60
R1828-01	For high energy physics, fast time response, high gain				Bi	K	5	L/12	E678-20A★	3000	0.2	60	80
R2059	Variant of R1828-01 with synthetic silica window	400S	160~650	420	Bi	Q	5	L/12	E678-20A★	3000	0.2	60	80
PM55	S-20 response, general purpose	500K (S-20)	300~850	420	M	K	1	B/10	E678-14A■	1800	0.3	100	150
R550	High gain and low dark current variant of PM55				M	K	1	B/10	E678-14A■	1500	0.3	100	150

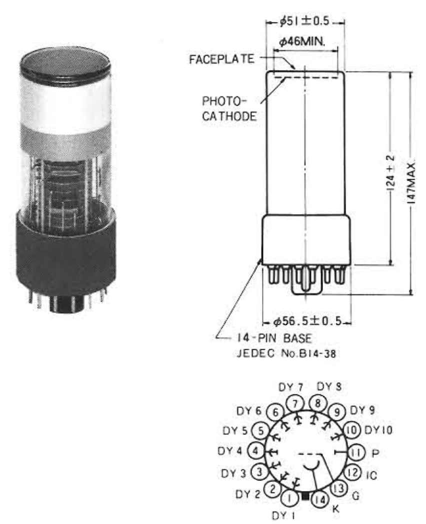
(A) * : Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on pages 76 and 77.
(C) Photocathode materials
- Bi : Bialkali
- M : Multialkali

(D) Window materials
- K : Borosilicate glass
- Q : Synthetic silica

(E) Basing diagram symbols are explained on page 17.
(F) Dynode Structure
- B : Box-and-grid
- B + M : Box-and-grid and mesh combination
- M : Proximity mesh
- L : Linear focused

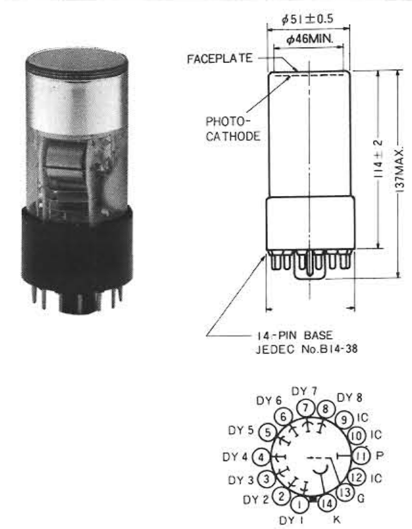
(G) ★: A socket will be supplied with a tube.
■: Sockets may be available from electronics supply houses or our sales offices.
(H) The maximum ambient temperature range is −80 to +50°C.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).

1 7696, R878 etc.



Bottom View

2 R1306



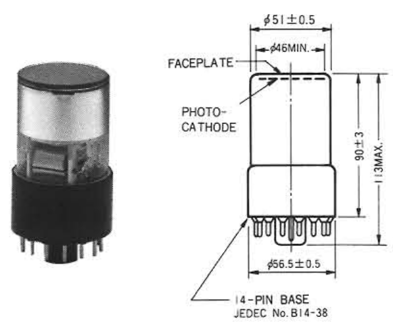
Bottom View

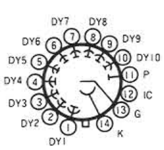
(at 25°C)

Cathode Sensitivity: Blue Typ. (µA/lm-b)	Cathode Sensitivity: Red/White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M): Anode Sensitivity, Luminous Min. (A/lm)	Anode Sensitivity, Luminous Typ. (A/lm)	Anode Sensitivity, Radiant Typ. (K) (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	(A) Type No.
—	—	64	1250 ⑫	20	50	4.0×10^4	6.3×10^5	2	20	7.0	70	Silica window type (R208) available.	**7696**
11.5	—	90	1000 ⑥	3	30	2.9×10^4	3.2×10^5	2	20	7.0	60	Silica window type (R2220) available.	**R1306**
11.5	—	90	1000 ⑫	3	30	2.7×10^4	3.0×10^5	2	20	4.8	45		**R1847-07***
11.5	—	90	1250 ⑫	20	70	6.7×10^4	7.4×10^5	5	50	7.0	70	Venetian blind dynode type (R1507), Silica window type (R1791) available.	**R878**
7.0	—	65	1250 ⑪	2	10	1.1×10^4	1.7×10^5	5	50	6.0	—		**R1840**
10.5	—	80	2500 ㉔	200	1600	1.6×10^6	2.0×10^7	50	400	1.3	28		**R1828-01**
10.5	—	80	2500 ㉔	200	1600	1.6×10^6	2.0×10^7	50	400	1.3	28		**R2059**
—	0.2	64	1500 ⑫	10	50	2.1×10^4	3.3×10^5	10	30	6.5	60		**PM55**
—	0.2	64	1000 ⑫	20	100	4.3×10^4	6.7×10^5	10	30	8.0	75		**R550**

Unit: mm

③ R1847-07

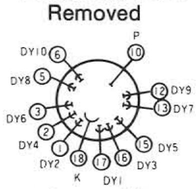




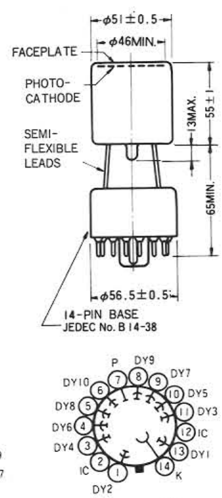
Bottom View

④ R1840

Temporary Base Removed

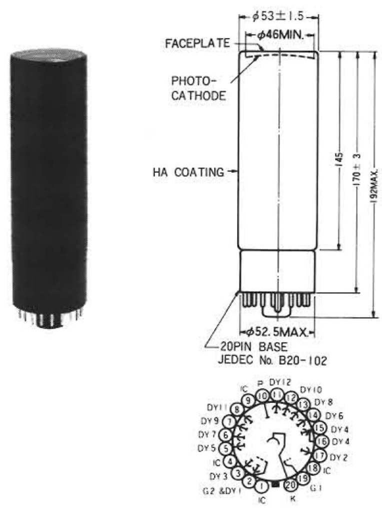


Bottom View



Bottom View

⑤ R1828-01, R2059



Bottom View

Head-On Type Photomultiplier Tubes

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity Luminous Min. (µA/lm)	Cathode Sensitivity Luminous Typ. (µA/lm)
2 inch (51 mm) Dia. Types with Glass Base													
* R2050	For vacuum UV detection, MgF_2 window	100M	115 ~ 200	140	Cs-I	MF	1	B+V/12	E678-19A	3000	0.1	—	—
R2083	Subnanosecond rise time, coaxial anode output	400K	300 ~ 650	420	Bi	K	2	L/8	E678-19C	3500	0.2	60	80
R329	For scintillation counting, fast time response				Bi	K	3	L/12	E678-21A	2700	0.2	60	80
R329-02	HA Coating variant of R329				Bi	K	4	L/12	E678-21A	2700	0.2	60	80
R331-05	For liquid scintillation counting, spherical window				Bi	K	5	L/12	E678-21A	2500	0.2	60	80
R1332	For photon counting, GaAsP first dynode				Bi	K	4	L/12	E678-21A	2700	0.1	50	70
R464	For photon counting, bialkali photocathode				Bi	K	6	B/12	E678-21A	1500	0.01	30	50
R331	Variant of R331-05 with synthetic silica window	400S	160 ~ 650	420	Bi	Q	5	L/12	E678-21A	2500	0.2	60	80
R2014	For liquid scintillation counting				Bi	Q	7	B+V/12	E678-19A	1600	0.2	60	80
R585	For photon counting, variant of R464 with silica window				Bi	Q	6	B/12	E678-21A	1500	0.01	30	50
R1044	High temp. bialkali photocathode	401K	300 ~ 650	375	H Bi	K	7	B/12	E678-19A	2000	0.2	—	40
R1640	High temp. bialkali photocathode, ruggedized type				H Bi	K	8	L/12	E678-21A	2500	0.2	—	40
R649	For photon counting, variant of R464 with S-20 response	500K (S-20)	300 ~ 850	420	M	K	6	B/12	E678-21A	1500	0.01	80	120

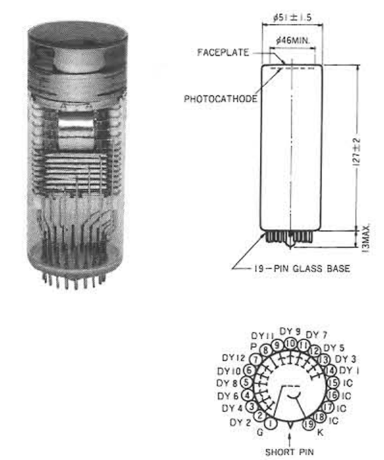
(A) * : Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on pages 76 and 77.
(C) Photocathode materials
- Bi : Bialkali
- H Bi : High temperature bialkali
- M : Multialkali

(D) Window materials
- MF : MgF_2
- K : Borosilicate glass
- Q : Synthetic silics

(E) Basing diagram symbols are explained on page 17.
(F) Dynode Structure
- L : Linear focused
- B : Box-and-grid
- B + V : Box-and-grid and venetian blind combination

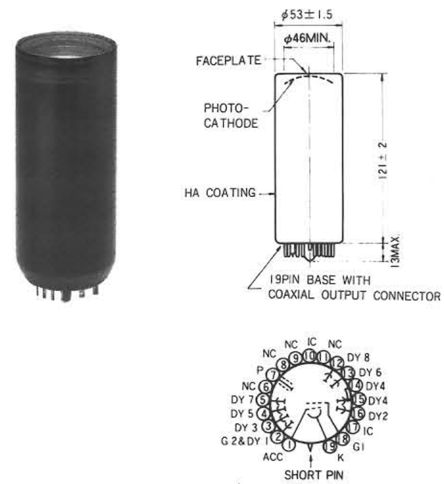
(G) A socket will be supplied with a tube.
(H) The maximum ambient temperature range is −80 to +50°C except high temperature bialkali photocathode types which withstand up to +175°C. When using tubes with glass base at −30°C or below, see precautions on page 74.

1 R2050



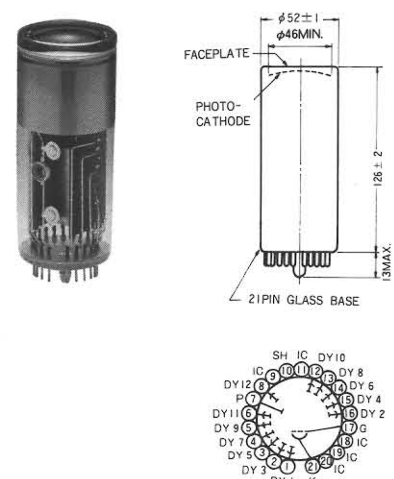
Bottom View

2 R2083



Bottom View

3 R329, R1640



Bottom View

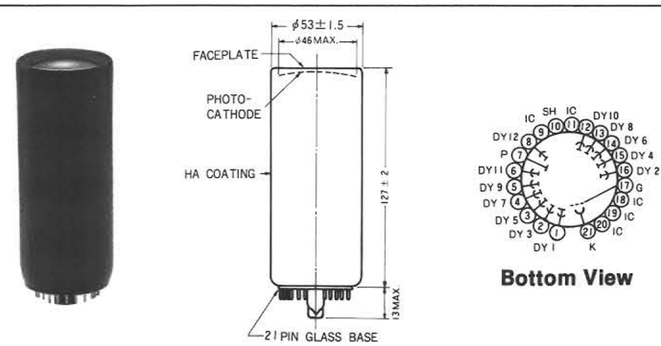
(at 25°C)

Cathode Sensitivity: Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Ⓚ Radiant Typ. (mA/W)	Ⓛ Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics Ⓜ: Anode Sensitivity, Luminous Min. (A/lm)	Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Ⓚ Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Max. (nA)	Time Response: Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)	Notes	Ⓐ Type No.
—	—	9.8[b]	2000 ㉓	—	—	2.9×10^{3} [b]	3.0×10^5	0.04	0.07	—	—		**R2050***
10.0	—	80	3000 ⑦	30	80	8.0×10^4	1.0×10^6	100	800	0.7	16	Assembled type (H2431) is recommended.	**R2083**
10.5	—	80	1500 ㉖	15	100	1.0×10^5	1.3×10^6	6	40	2.6	48	Silica window type (R2256), S-25 type (R2257) available.	**R329**
10.5	—	80	1500 ㉖	15	100	1.0×10^5	1.3×10^6	6	40	2.6	48		**R329-02**
10.5	—	80	1500 ㉖	30	120	1.2×10^5	1.5×10^6	18[c] cpm	—	2.6	48		**R331-05**
9.0	—	72	1500 ㉘	20	70	7.2×10^4	1.0×10^6	4	40	3.0	43		**R1332**
—	—	50	1000 ㉗	100	300	3.0×10^5	6.0×10^6	5[a] cps	15[a] cps	13	70		**R464**
10.5	—	80	1500 ㉖	30	120	1.2×10^5	1.5×10^6	3	—	2.6	48		**R331**
9.5	—	80	1250 ㉓	100	800	8.0×10^5	1.0×10^7	30	200	7.2	62		**R2014**
—	—	50	1000 ㉗	100	300	3.0×10^5	6.0×10^6	5[a] cps	15[a] cps	13	70		**R585**
6.0	—	50	1500 ㉓	10	60	7.5×10^4	1.5×10^6	3	50	10	60		**R1044**
6.0	—	50	2000 ㉖	10	30	3.8×10^4	7.5×10^5	10	200	2.3	45		**R1640**
—	0.2	51	1000 ㉗	100	800	3.4×10^5	6.7×10^6	200[a] cps	350[a] cps	13	70		**R649**

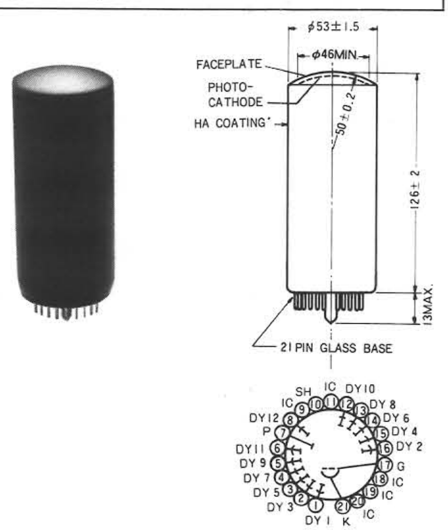
Ⓙ Averaged over any interval of 30 seconds maximum.
Ⓚ At the wavelength of peak response.
Ⓛ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓜ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓛ.
a : Dark counts per second (cps)
b : At 122 nm
c : Background noise

Unit: mm

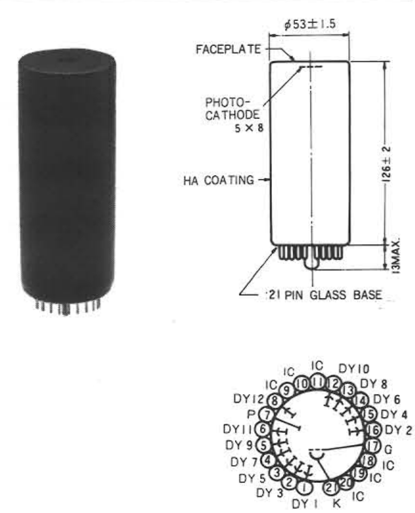
④ R329-02, R1332



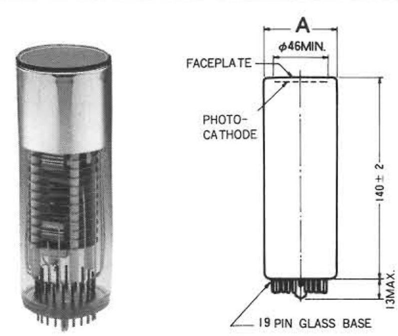
⑤ R331, R331-05



⑥ R464, R585, R649

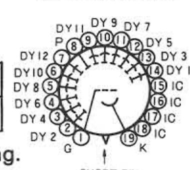


⑦ R1044, R2014



	R1044	R2014
A	φ51 ± 1.0	φ52 ± 1.5

R2014 has an HA coating.



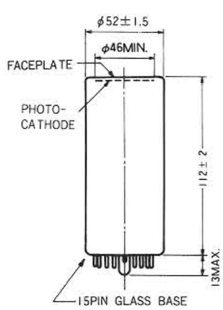
Head-On Type Photomultiplier Tubes

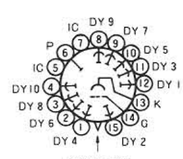
Type No.	Remarks	Spectral Response Ⓐ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	Ⓑ Photocathode Material	Ⓒ Window Material	Ⓓ Outline No.	Ⓔ Dynode Structure / No. of Stages	Ⓕ Socket	Maximum Ratings Ⓖ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓗ Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
2 inch (51 mm) Dia. Types with Glass Base (Cont'd)													
R375	Wide spectral response, multialkali photocathode	500S	160~850	420	M	Q	❶	B/10	E678-15A★	1500	0.1	80	150
R562	Wide spectral response, multialkali photocathode				M	Q	❷	B/10	E678-19A★	1500	0.1	100	150
R1333	For photon counting, GaAsP first dynode	501K	300~900	650	M	K	❸	L/12	E678-21A★	2700	0.1	140	230
R669	Extended red multialkali photocathode				M	K	❹	B/10	E678-15A★	1500	0.1	140	230
R1017	Extended red multialkali photocathode				M	K	❺	B/12	E678-21A★	1500	0.1	140	230
R943-02	For photon counting, GaAs photocathode	650S	160~930	300~800	GaAs(Cs)	Q	❻	L/10	E678-21A★	2200	0.001	300	600
2-1/2 inch (63 mm) Dia. Type													
R1410	For scintillation counting, 8-stage	400K	300~650	420	Bi	K	❼	B/8	E678-14A■	1500	0.1	80	95

Ⓐ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓑ Photocathode materials
  M : Multialkali
  Bi : Bialkali
Ⓒ Window materials
  Q : Synthetic silica
  K : Borosilicate glass
Ⓓ Basing diagram symbols are explained on page 17.
Ⓔ Dynode Structure
  B : Box-and-grid
  L : Linear focused
Ⓕ ★: A socket will be supplied with a tube.
  ■: Sockets may be available from electronics supply houses or our sales offices.

Ⓖ The maximum ambient temperature range is −80 to +50°C. When using tubes with glass base at −30°C or below, see precautions on page 74.
Ⓗ Averaged over any interval of 30 seconds maximum.
Ⓙ At the wavelength of peak response.
Ⓚ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓛ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓚ.
a: Dark counts per second (cps) after an hour storage at −20°C.

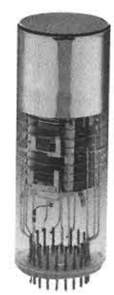
❶ R375

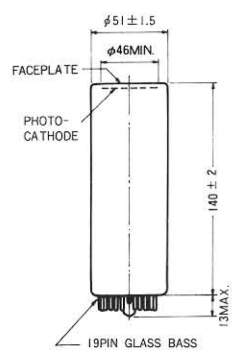


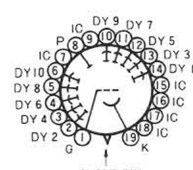


Bottom View

❷ R562







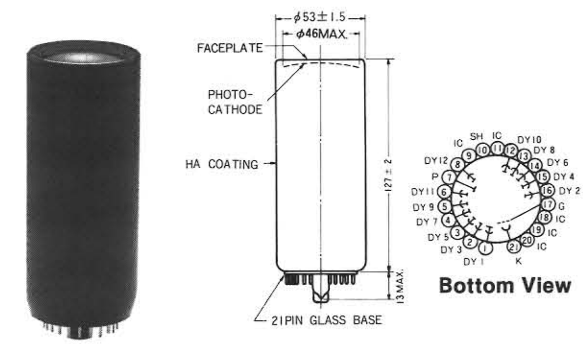
Bottom View

(at 25°C)

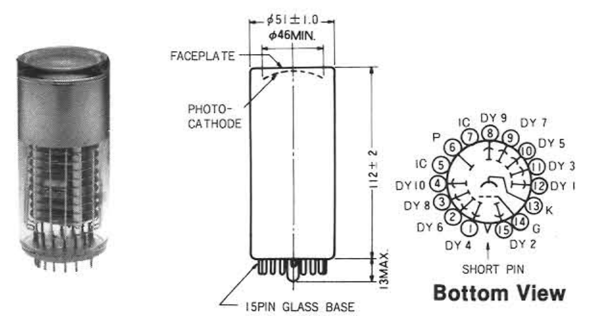
Cathode Sensitivity			Anode to Cathode Supply Voltage	Anode Characteristics								Notes	Type No.
				Anode Sensitivity			Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response			
				Luminous		Radiant Typ.							
Blue Typ. (μA/lm-b)	Red/White Ratio Typ.	Radiant Typ. (mA/W)	(Vdc)	Min. (A/lm)	Typ. (A/lm)	(A/W)		Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)		
—	0.2	64	1000 (12)	20	100	4.3×10^4	6.7×10^5	5	20	9.0	70		R375
—	0.2	64	1000 (12)	20	80	3.4×10^4	5.3×10^5	5	20	9.0	70	Borosilicate glass window type (R922) available.	R562
—	0.35	50	1500 (28)	30	100	2.2×10^4	4.3×10^5	50	200	3.0	43		R1333
—	0.35	50	1000 (12)	20	75	1.7×10^4	3.3×10^5	7	15	9.0	70		R669
—	0.35	50	1000 (26)	20	100	2.2×10^4	4.3×10^5	9	15	16	—		R1017
—	0.58	71	1500 (19)	150	300	3.6×10^4	5.0×10^5	20[a] cps	50[a] cps	3.0	23	K free borosilicate glass window type (R943-05) available.	R943-02
11.5	—	90	1000 (6)	3	30	2.9×10^4	3.2×10^5	2	20	8.0	64		R1410

Unit: mm

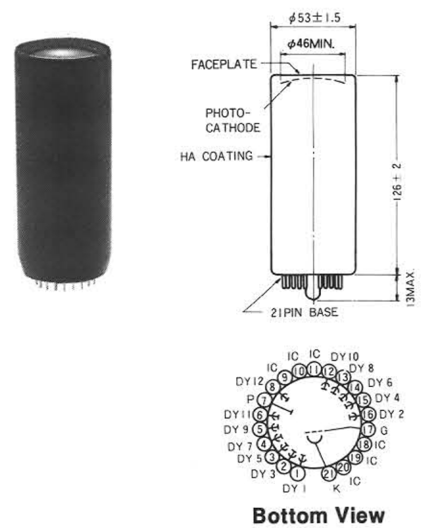
3 R1333



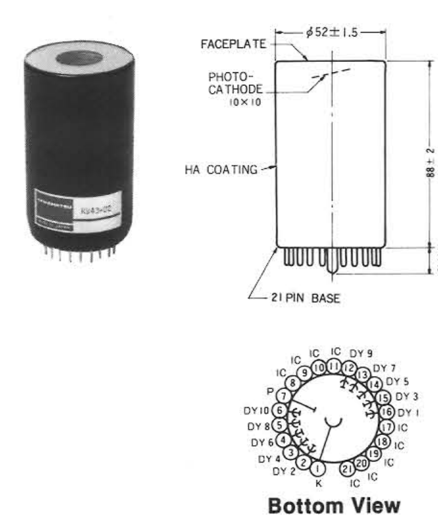
4 R669



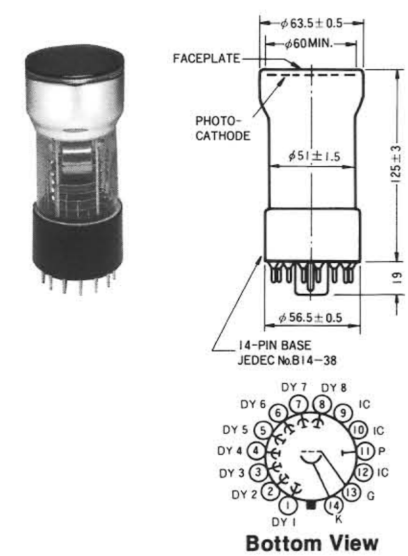
5 R1017



6 R943-02



7 R1410

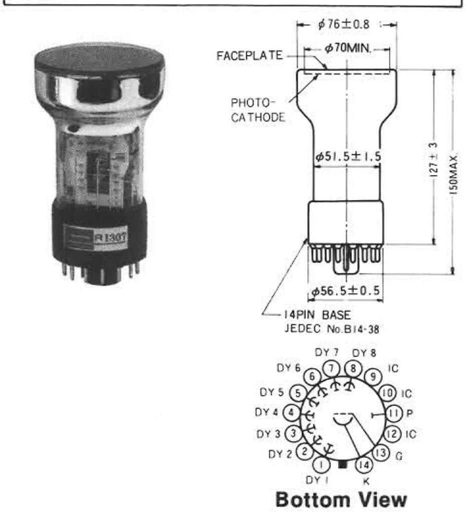


Head-On Type Photomultiplier Tubes

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity: Luminous Min. (µA/lm)	Cathode Sensitivity: Luminous Typ. (µA/lm)
3 inch (76 mm) Dia. Types													
R1307	For scintillation counting, 8-stage	400K	300~650	420	Bi	K	1	B/8	E678-14A■	1500	0.1	80	95
*R1848-07	For scintillation counting, low porfile	400K	300~650	420	Bi	K	2	B+M/10	E678-14A■	1500	0.1	80	100
R594	For scintillation counting, 10-stage	400K	300~650	420	Bi	K	3	B/10	E678-14A■	2000	0.1	70	95
R1911-01	Good combination of PHR and pulse linearity	400K	300~650	420	Bi	K	4	B+M/10	E678-14A■	1800	0.1	70	95
R2238	High pulse linearity, good immunity to magnetic field	400K	300~650	420	Bi	K	5	M/12	E678-14A■	1500	0.1	40	60
5 inch (127 mm) Dia. Types													
R877	For scintillation counting, 10-stage	400K	300~650	420	Bi	K	6	B/10	E678-14A■	1500	0.1	60	90
R1512	Variant of R877 with venetian blind dynodes	400K	300~650	420	Bi	K	6	VB/10	E678-14A■	2000	0.1	70	90
R1250	For high energy physics, fast time response, high gain	400K	300~650	420	Bi	K	7	L/14	E678-20A★	3000	0.2	55	70
R1513	Variant of R1512 with S-20 response	500K (S-20)	300~850	420	M	K	6	VB/10	E678-14A■	2000	0.1	100	150

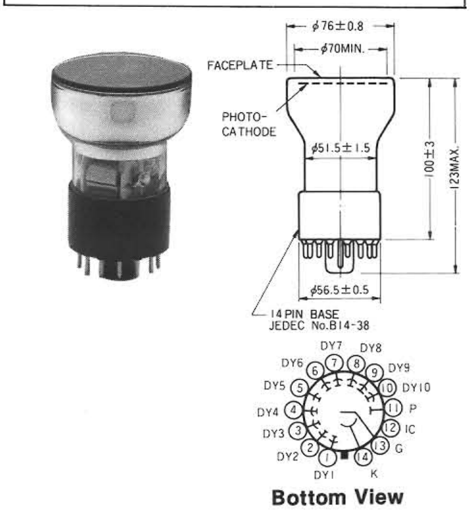
(A) * : Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on pages 76 and 77.
(C) Photocathode materials
  Bi : Bialkali
  M : Multialkali
(D) Window materials
  K : Borosilicate glass
(E) Basing diagram symbols are explained on page 17.
(F) Dynode structure
  B : Box-and-grid
  B + M : Box-and-grid and mesh combination
  M : Proximity Mesh
  VB : Venetian blind
  L : Linear focused
(G) ★: A socket will be supplied with a tube.
  ■: Sockets may be available from electronics supply houses or our sales offices.
(H) The maximum ambient temperature range is −80 to +50°C.
(J) Averaged over any interval of 30 seconds maximum.
(K) At the wavelength of peak response.
(L) Voltage distribution ratios used to measure characteristics are shown on page 62.
(M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).

1 R1307



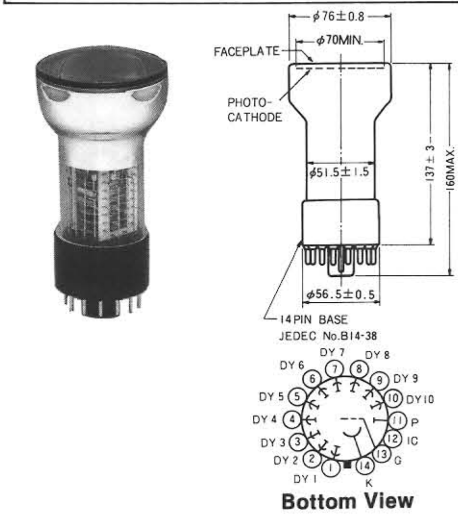
Bottom View

2 R1848-07



Bottom View

3 R594



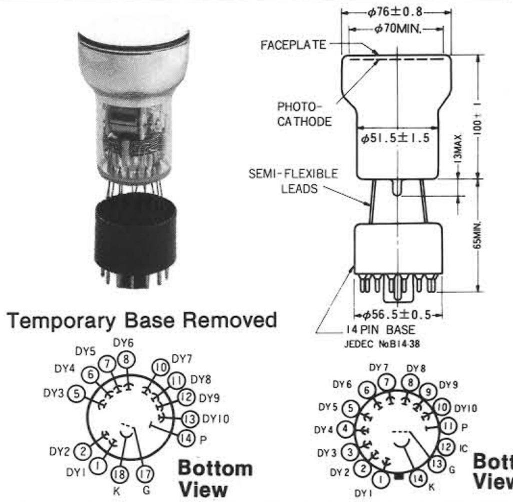
Bottom View

(at 25°C)

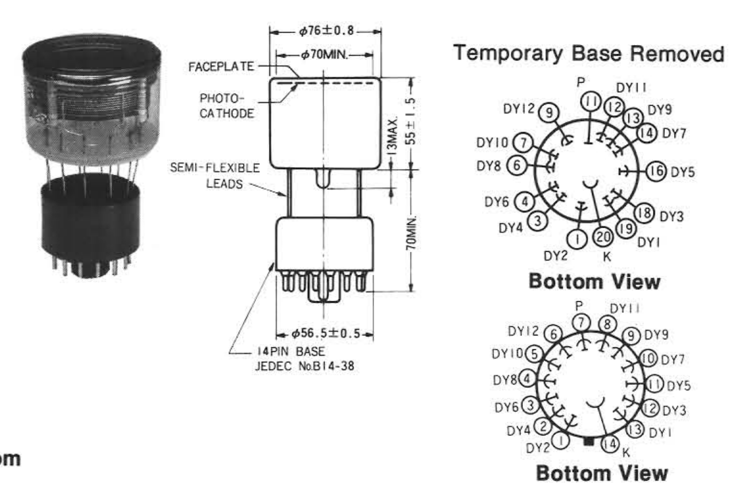
Cathode Sensitivity Blue Typ. (μA/lm-b)	Cathode Sensitivity (K) Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M): Anode Sensitivity, Luminous Min. (A/lm)	Anode Sensitivity, Luminous Typ. (A/lm)	Anode Sensitivity (K) Radiant Typ. (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	(A) Type No.
11.5	90	1000 ⑥	3	30	2.9×10^4	3.2×10^5	2	20	8.0	64		R1307
11.5	90	1000 ⑫	3	30	2.7×10^4	3.0×10^5	2	50	6.0	47		R1848-07*
11.5	90	1500 ⑫	10	70	6.7×10^4	7.4×10^5	5	70	7.0	65		R594
11.5	90	1500 ⑯	10	30	2.9×10^4	3.2×10^5	5	70	11	64		R1911-01
7.0	65	1250 ㉕	3	30	3.3×10^4	5.0×10^5	5	50	5.5	17		R2238
11.0	85	1250 ⑫	20	40	3.7×10^4	4.4×10^5	10	50	10	90	K-free window type (R877-01), silica window type (R1836) available.	R877
11.0	85	1500 ⑫	20	100	9.4×10^4	1.1×10^6	20	100	9.0	82		R1512
9.0	72	2000 ㉚	300	1000	1.0×10^6	1.4×10^7	50	600	2.5	54	Convex-concave UV glass window type (R1584) available.	R1250
—	64	1500 ⑫	10	50	2.1×10^4	3.3×10^5	30	150	9.0	82		R1513

Unit: mm

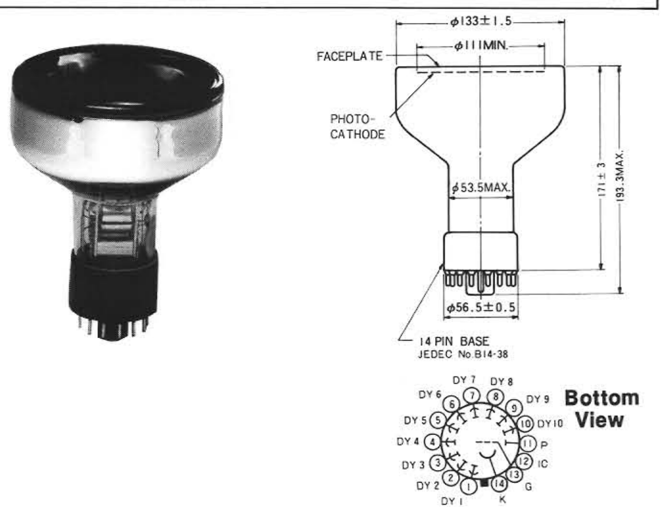
④ R1911-01



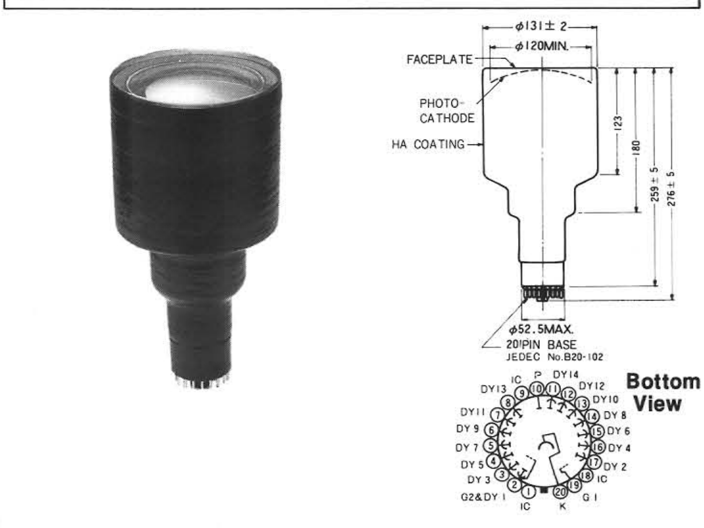
⑤ R2238



⑥ R877, R1512, R1513



⑦ R1250

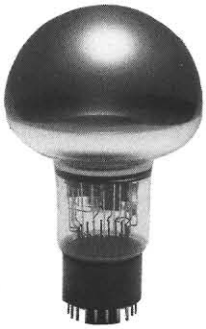


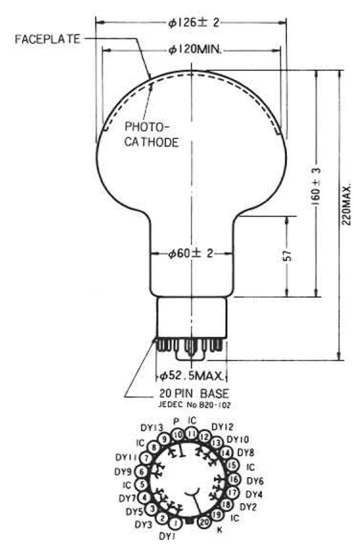
Hemispherical Envelope Photomultiplier Tubes

Type No.	Remarks	Spectral Response Ⓐ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	Ⓑ Photocathode Material	Ⓒ Window Material	Ⓓ Outline No.	Ⓔ Dynode Structure / No. of Stages	Ⓕ Socket	Maximum Ratings Ⓖ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓗ Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µA/lm)	Cathode Sensitivity Luminous Typ. (µA/lm)
Hemispherical Envelope Types													
R2218	For high energy physics, 5" diameter	400K	300 ~ 650	420	Bi	K	❶	VB/13	E678-20A	1800	0.1	40	75
R1408	For high energy physics, 8" diameter				Bi	K	❷	VB/13	E678-20A	1800	0.1	40	75
R1449	For high energy physics, 20" diameter				Bi	K	❸	VB/13	E678-20A	2800	0.1	40	60

Ⓐ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓑ Photocathode materials
Bi : Bialkali
Ⓒ Window materials
K : Borosilicate glass
Ⓓ Basing diagram symbols are explained on page 17.
Ⓔ Dynode Structure
VB : Venetian blind
Ⓕ A socket will be supplied with a tube.
Ⓖ The maximum ambient temperature range is −80 to +50°C.
Ⓗ Averaged over any interval of 30 seconds maximum.
Ⓙ At the wavelength of peak response.
Ⓚ Voltage distribution ratios used to measure characteristics are shown on page 62.
Ⓛ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓚ .

❶ R2218





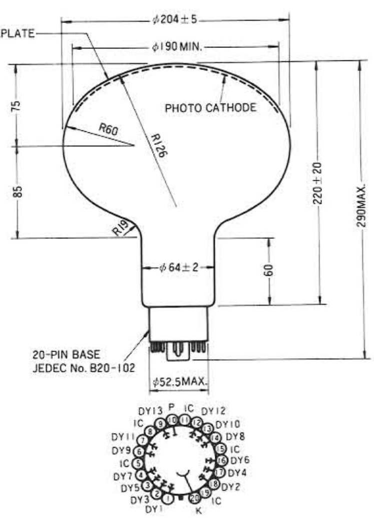
Bottom View

(at 25°C)

Cathode Sensitivity		Anode to Cathode Supply Voltage (K)	Anode Characteristics (L)									Notes	Type No.
			Anode Sensitivity			Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response				
			Luminous		Radiant (J)								
Blue Typ.	Radiant (J) Typ.		Min.	Typ.	Typ.		Typ.	Max.	Rise Time Typ.	Electron Transit Time Typ.			
(μA/lm-b)	(mA/W)	(Vdc)	(A/lm)	(A/lm)	(A/W)		(nA)	(nA)	(ns)	(ns)			
8.0	80	1500 (29)	200	3750	4.0×10^6	5.0×10^7	150	1000	6.5	55			R2218
8.0	80	1500 (29)	200	3750	4.0×10^6	5.0×10^7	150	1000	6.5	60			R1408
7.0	65	2000 (29)	60	600	6.5×10^5	1.0×10^7	200	1000	18	90			R1449

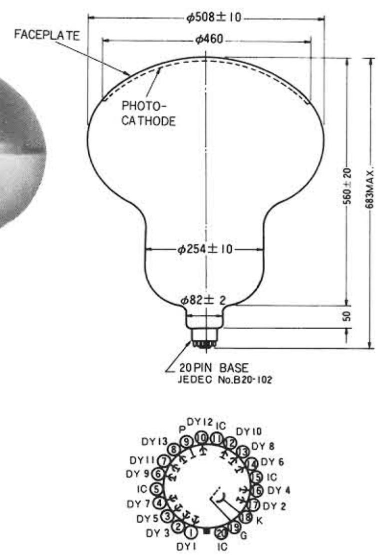
Unit: mm

(2) R1408



Bottom View

(3) R1449



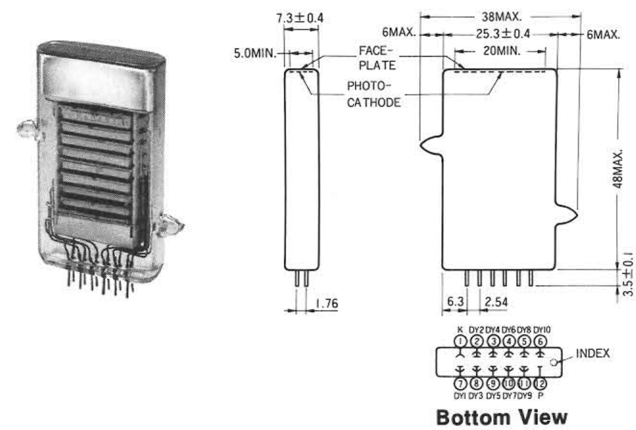
Bottom View

Special Envelope Photomultiplier Tubes

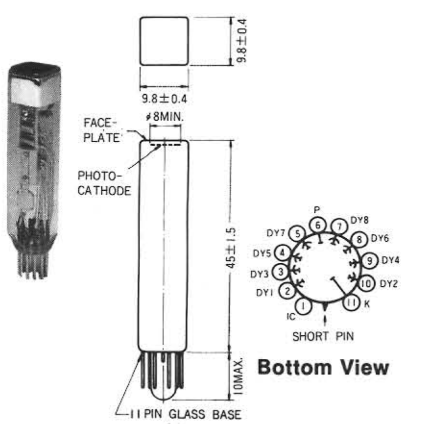
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (mA) (J)	Cathode Sensitivity Luminous Min. (μA/lm)	Cathode Sensitivity Luminous Typ. (μA/lm)
Square, Rectangular or Hexagonal Faceplate Types													
*R2937	Slit shape faceplate	400K	300 ~ 650	420	Bi	K	1	VB/10	E678-12E★	1200	0.01	40	60
R2248	3/8" × 3/8" square shape				Bi	K	2	L/8	E678-11N★	1500	0.01	60	85
R2102	1/2" × 1/2" square shape				Bi	K	3	L/10	E678-13A★	1250	0.1	40	80
*R2497	1" × 1" square shape				Bi	K	4	L/10	E678-12A★	1800	0.1	70	100
R2080	Variant of R2102 with half photocathode gating				Bi	K	3	L/10	E678-13A★	1250	0.1	40	80
R1548	Rectangular, dual structure				Bi	K	5	L/10	E678-17A★	1750	0.1	60	80
R1612	For scintillation counting 88×40mm rectangular shape				Bi	K	6	B/10	E678-14A■	1250	0.1	40	70
R1534-01	For scintillation counting, 51×51 mm square shape				Bi	K	7	B/8	E678-14A■	1500	0.1	80	100
R1538-01	For scintillation counting, 2.5" dia. hexagonal shape				Bi	K	8	B/8	E678-14A■	1500	0.1	80	100
R1537-01	For scintillation counting, 3" dia. hexagonal shape				Bi	K	9	B/8	E678-14A■	1500	0.1	80	100

- (A) *: Newly listed in this catalog.
- (B) Typical spectral response characteristics are shown on pages 76 and 77.
- (C) Photocathode materials
  - Bi : Bialkali
- (D) Window materials
  - K : Borosilicate glass
- (E) Basing diagram symbols are explained on page 17.
- (F) Dynode structure
  - VB : Venetian blind
  - L : Linear focused
  - B : Box-and-grid
- (G) ★: A socket will be supplied with a tube.
  - ■: Sockets may be available from electronics supply houses or our sales offices.
- (H) The maximum ambient temperature range is −80 to +50°C. When using tubes with glas base at −30°C or below, see precautions on page 74.
- (J) Averaged over any interval of 30 seconds maximum.
- (K) At the wavelength of peak response.
- (L) Voltage distribution ratios used to measure characteristics are shown on page 62.
- (M) Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note (L).

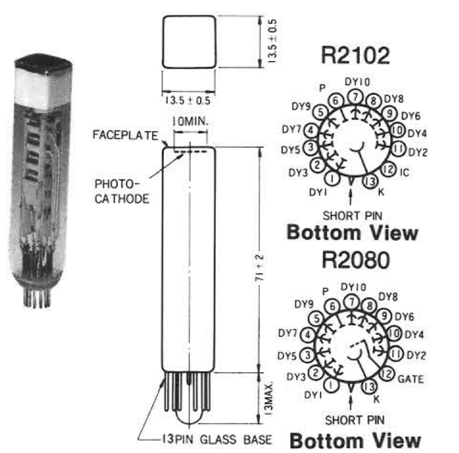
1 R2937



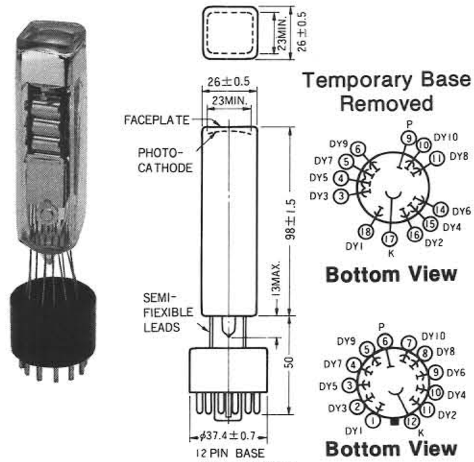
2 R2248



3 R2102, R2080



4 R2497

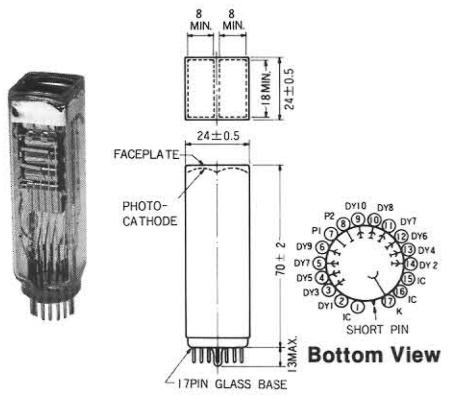


(at 25°C)

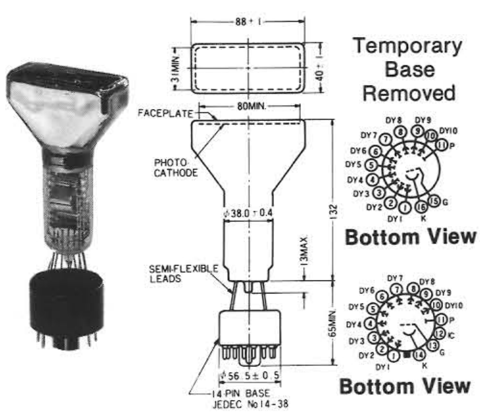
Cathode Sensitivity Blue Typ. (μA/lm-b)	Cathode Sensitivity Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (K) (A/W)	Current Amplification Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes	Type No. (A)
7.5	58	1000 (10)	50	120	1.2×10^5	2.0×10^6	5	30	5.0	35	Multialkali type (R2366) available.	**R2937***
10.5	82	1250 (5)	30	85	8.2×10^4	1.0×10^6	5	50	0.9	7.8		**R2248**
10.5	80	1000 (11)	30	80	8.0×10^4	1.0×10^6	5	15	2.5	24		**R2102**
11.5	88	1500 (18)	60	300	2.6×10^5	3.0×10^6	50	100	2.4	22		**R2497***
10.5	80	1000 (11)	30	100	1.0×10^5	1.3×10^6	5	15	2.3	24		**R2080**
9.5	75	1250 (20)	50	200	1.9×10^5	2.5×10^6	20	250	1.8	20		**R1548**
9.0	72	1000 (12)	5	30	3.1×10^4	4.3×10^5	4	30	13	100		**R1612**
11.5	90	1000 (6)	5	50	4.5×10^4	5.0×10^5	5	20	8.0	60		**R1534-01**
11.5	90	1000 (6)	5	50	4.5×10^4	5.0×10^5	5	20	8.0	60		**R1538-01**
11.5	90	1000 (10)	5	50	4.5×10^4	5.0×10^5	5	20	10	65		**R1537-01**

Unit: mm

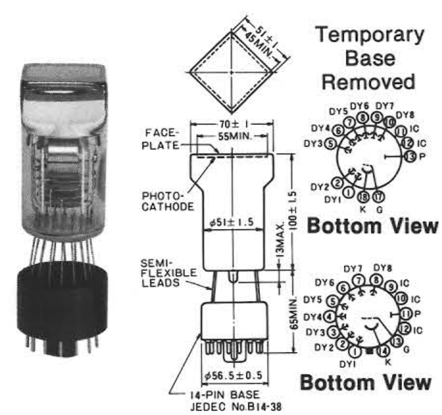
5 R1548



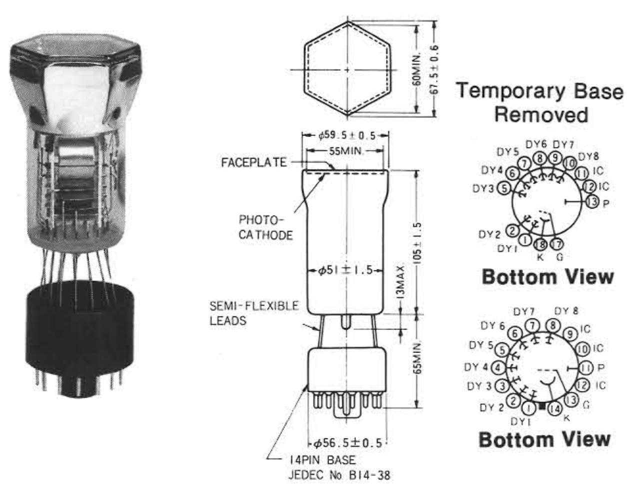
6 R1612



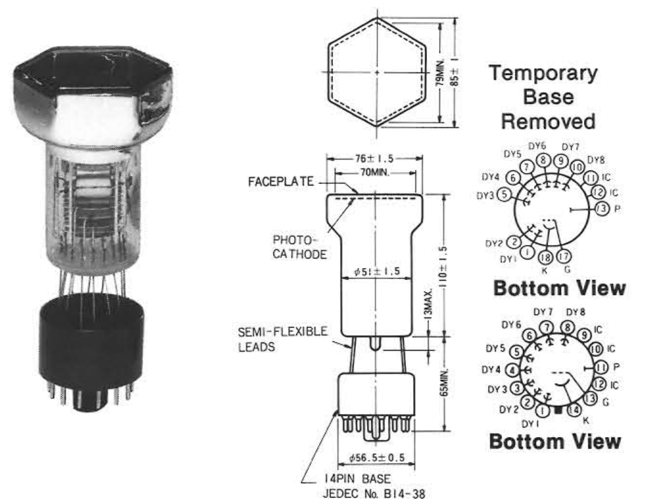
7 R1534-01



8 R1538-01



9 R1537-01



Microchannel Plate-Photomultiplier Tubes (MCP-PMTs)

(For further information, a technical data sheet is available.)

Ⓐ Type No.	Remarks	Spectral Response Ⓑ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wave-length (nm)	Photo-cathode Material	Ⓒ Window Material	Out-line No.	No. of MCP Stage	Maximum Ratings Ⓓ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓓ Anode Current Conti-nuous (nA)	Maximum Ratings Ⓓ Anode Current Pulsed Peak (nA)	Terminals −HV Input	Terminals Signal Output
Electrostatic Focus Types													
R1644U	1-stage MCP	402K	300 ~ 650	375	Bialkali	K	❶	1	2900	100	700	MHV-R	BNC-R
R1645U	2-stage MCP	402K	300 ~ 650	375	Bialkali	K	❶	2	3400	100	700	MHV-R	BNC-R
R2286U	3-stage MCP	402K	300 ~ 650	375	Bialkali	K	❶	3	4200	100	700	MHV-R	BNC-R
Proximity Focus Types													
R1563U	1-stage MCP	402K	300 ~ 650	375	Bialkali	K	❷	1	2900	100	700	MHV-R	BNC-R
R1564U	2-stage MCP	402K	300 ~ 650	375	Bialkali	K	❷	2	3400	100	700	MHV-R	BNC-R
R2287U	3-stage MCP	402K	300 ~ 650	375	Bialkali	K	❷	3	4200	100	700	MHV-R	BNC-R
*R2809U	6 μm type 2-stage MCP, small TTS	402K	300 ~ 650	375	Bialkali	K	❷	2	3400	100	700	MHV-R	BNC-R
Gated Electrostaic Focus Types													
R2024U	High speed gate operation of less than 5ns	402K	300 ~ 650	375	Bialkali	K	❸	2	3400	100	700	MHV-R	BNC-R[a]

Ⓐ *: Newly listed in this catalog.

Ⓑ Typical spectral response characteristics are shown on pages 76 and 77.

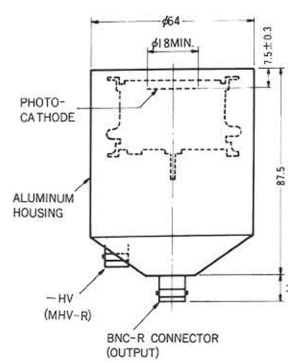
Ⓒ Window Materials
K: Borosilicate glass

Ⓓ The maximum ambient temperature range is −80 to +50°C.

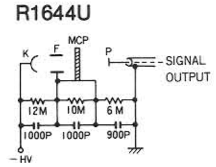
a : The connector of the gate signal input is also BNC-R.

b : Using an R2809U, a field data value of 22.5 ps T.T.S. was confirmed at the Institute for Molecular Science, Okazaki City, Japan through the good offices of Dr. Yamazaki. The difference between this data and catalog value is due to the difference of jitter in measurement systems (circuit, light source, etc.). A use of very low jitter systems is recommended.

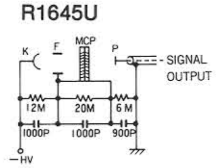
❶ R1644U, R1645U, R2286U



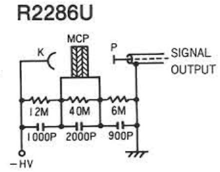
R1644U



R1645U



R2286U

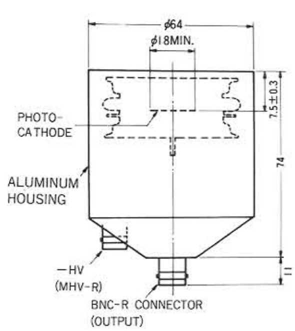


(at 25°C)

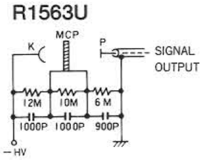
Cathode Sensitivity			Anode to Cathode Supply Voltage	Anode Characteristics									Type No. Ⓐ
Quantum Efficiency at 420 nm Typ.	Luminous Typ.	Blue Typ.		Anode Sensitivity		Current Amplification Typ.	Anode Dark Current (after 30 min.)		Time Response				
				Luminous Typ.	Blue Typ.		Typ.	Max.	Rise Time Typ.	Electron Transit Time Typ.	T.T.S. Typ.		
(%)	(μA/lm)	(μA/lm-b)	(Vdc)	(A/lm)	(A/lm-b)		(nA)	(nA)	(ns)	(ns)	(ps)		
15	50	7.0	2600	0.25	0.035	5×10^3	0.1	1	0.7	3.2	—	R1644U	
15	50	7.0	3000	25	3.5	5×10^5	1	5	0.24	3.5	100	R1645U	
15	50	7.0	3600	250	35	5×10^6	3	10	0.3	3.8	120	R2286U	
15	50	7.0	2600	0.25	0.035	5×10^3	0.1	1	0.16	0.4	—	R1563U	
15	50	7.0	3000	25	3.5	5×10^5	1	5	0.22	0.55	70	R1564U	
15	50	7.0	3600	250	35	5×10^6	3	10	0.28	0.62	90	R2287U	
15	50	7.0	3000	25	3.5	5×10^5	1	5	0.15	0.4	55[b]	R2809U*	
15	50	7.0	3000	25	3.5	5×10^5	1	5	0.3	3.5	170	R2024U	

Unit: mm

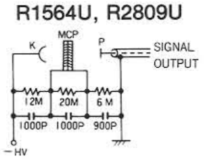
❷ R1563U, R1564U, R2287U, R2809U



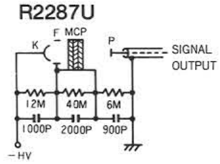
R1563U



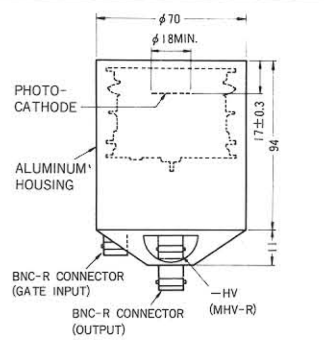
R1564U, R2809U

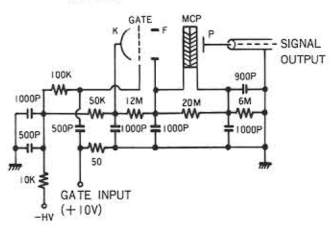


R2287U



❸ R2024U





Tubes for High Magnetic Environments

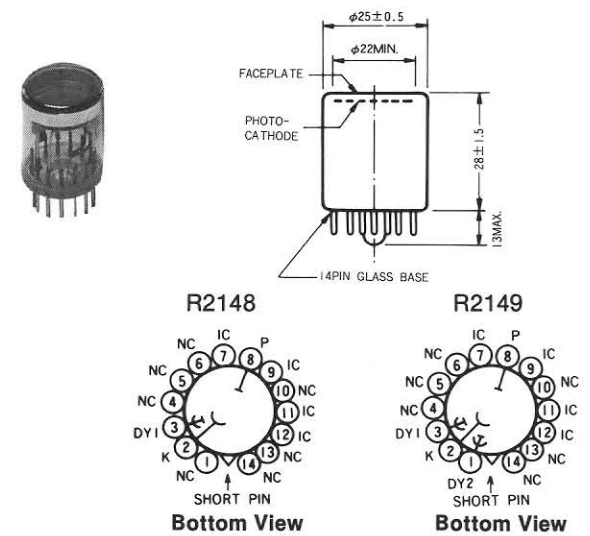
(For further information, a technical data sheet is available.)

Type No. Ⓐ	Tube Diameter inches(mm)	Outline No. Ⓑ	Spectral Response: Curve Code Ⓒ	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	No. of Dynode Stages	Socket Ⓓ	Maximum Ratings Ⓔ: Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓔ: Average Anode Current Ⓕ (mA)	Cathode Sensitivity: Quantum Efficiency at 390 nm Typ. (%)	Cathode Sensitivity: Luminous Typ. (μA/lm)
Triode Types											
R2148	1 (25)	❶	400K	300 ~ 650	420	1	E678-14C★	1200	0.001	20	60
R2184	2 (51)	❷					—				
R2046	3 (76)	❸									
Tetrode Types											
R2149	1 (25)	❶	400K	300 ~ 650	420	2	E678-14C★	1500	0.001	20	60
R2185	2 (51)	❷					—				
R2186	3 (76)	❸									
High Gain Types											
R2021	1.5 (38)	❹	400K	300 ~ 650	420	12	E678-14A▪	2500	0.1	22	70
*R2490-01	2 (51)	❺				16	E678-21A★	2700	0.1	22	70

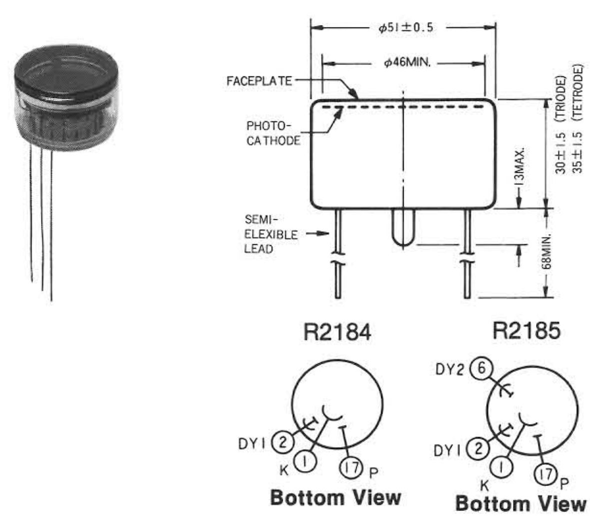
Ⓐ * : Newly listed in this catalog.
Ⓑ Basing diagram symbols are explained on page 17.
Ⓒ Typical spectral response characteristics are shown on pages 76 and 77.
Ⓓ ★: A socket will be supplied with a tube.
▪: Sockets may be available from electronics supply houses or our sales offices.
Ⓔ The maximum ambient temperature range is −80 to +50°C.
Ⓕ Averaged over any interval of 30 seconds maximum.
Ⓖ The supply voltage for Triode and Tetrode tubes is equally distributed to each electrode. For High gain types, see page 62 for the voltage distribution ratios.
Ⓗ Anode characteristics are measured with the supply voltage and the voltage distribution ratio specified by Note Ⓖ.

Note that tubes for high magnetic environments also have a excellent pulse linearity.

❶ R2148, R2149



❷ R2184, R2185



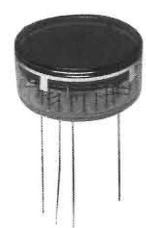
(at 25°C)

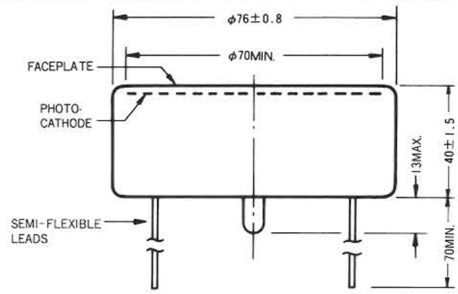
Cathode Sensitivity Blue Min. (μA/lm-b)	Cathode Sensitivity Blue Typ. (μA/lm-b)	Anode to Cathode Supply Voltage (Vdc)	Anode Luminous Sensitivity Ⓖ Typ. (A/lm)	Current Amplification at 0 gauss Typ.	Current Amplification at 5 kilo gauss Typ.	Current Amplification at 10 kilo gauss Typ.	Anode Dark Current (after 30 min.) Typ. (nA)	Anode Dark Current (after 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Type No. Ⓐ
5.0	7.0	1000	7.2×10^{-4}	12	7.8	7.2	0.7	—	—	—	R2148
											R2184
											R2046
5.0	7.0	1000	1.8×10^{-3}	30	15	10.5	1.0	—	—	—	R2149
											R2185
											R2186
7.0	8.0	2000 ㉕	3.5	5×10^{4}	1.5×10^{4}	1.5×10^{3}	30	300	2.5	12	R2021
		2500 ㉛	210	3×10^{6}	8×10^{5}	4.6×10^{4}	200	2000	2.7	14	R2490-01*

(Anode Characteristics Ⓗ)

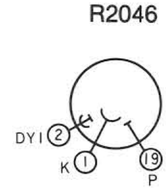
Unit: mm

❸ R2046, R2186

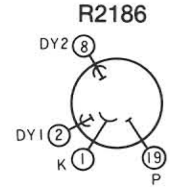




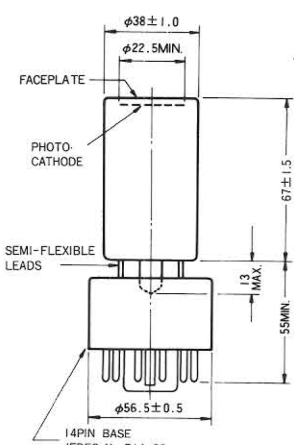
R2046



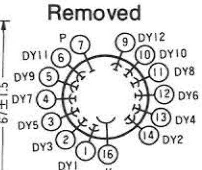
R2186



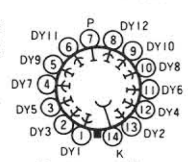
❹ R2021



Temporary Base Removed

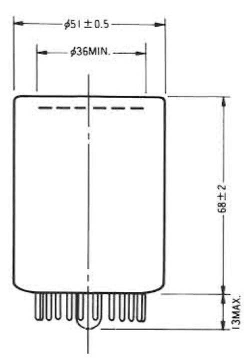


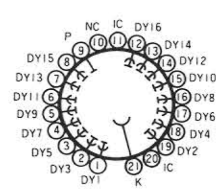
Bottom View



Bottom View

❺ R2490-01





Bottom View

Position Sensitive Photomultiplier Tubes

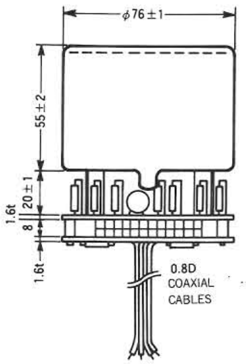
(For further information, a technical data sheet is available.)

Type No. (A)	Tube Diameter	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Dynode Structure / No. of Stages	No. of Anode Wires	Effective Photocathode Area Min. (mm)	Maximum Ratings (C): Anode to Cathode Supply Voltage (Vdc)	Maximum Ratings (C): Average Anode Current (D) (mA)	Cathode Sensitivity: Luminous Typ. (μA/lm)	Cathode Sensitivity: Blue (μA/lm-b)	Anode Characteristics: Anode to Cathode Supply Voltage (Vdc)	Anode Sensitivity: Radiant (E) Typ. (A/W)	Anode Sensitivity: Luminous Typ. (A/lm)	Current Amplification Typ.	Anode Dark Current after 30 min. Typ. (nA)
*R2486-02	3"Dia.	403K	300 ~ 600	420	Mesh / 12	12(X)×12(Y)	40(X)×40(Y)	1300	0.1	60	7.0	1250	6.0×10^3	60	1.0×10^5	20
*R2487-02	3"×3"	403K	300 ~ 600	420	Mesh / 12	18(X)×17(Y)	55(X)×45(Y)	1300	0.1	60	7.0	1250	6.0×10^3	60	1.0×10^5	20

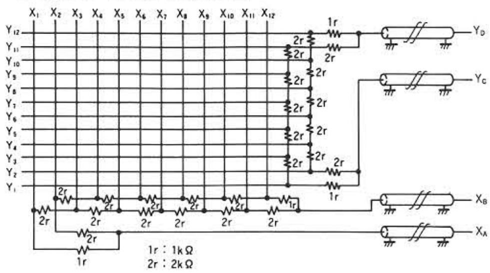
(A) *: Newly listed in this catalog.
(B) Typical spectral response characteristics are shown on page 76 and 77.
(C) The maximum ambient temperature range is −80 to +50°C.
(D) Average over any interval of 30 seconds maximum.
(E) At the wavelength of peak response.

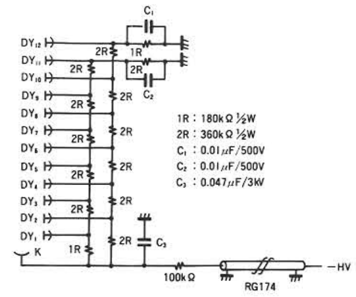
Unit: mm

R2486-02

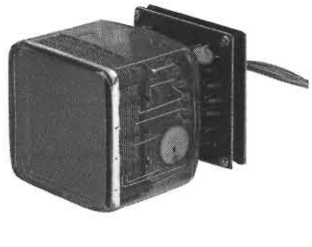


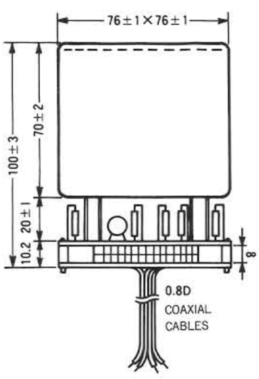
Crossed Wire Anodes



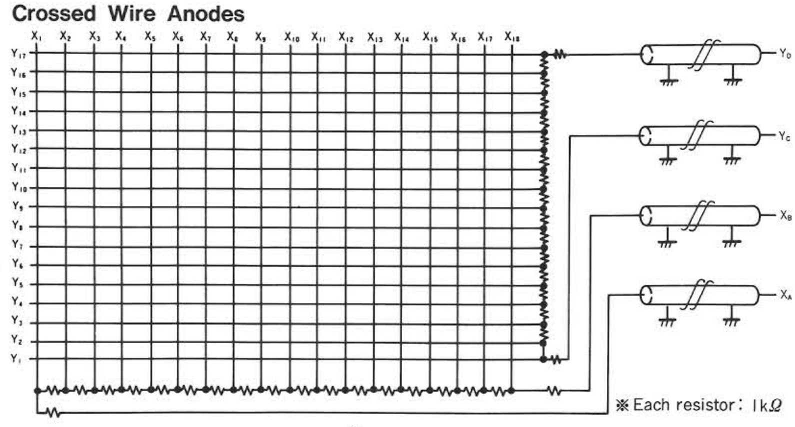


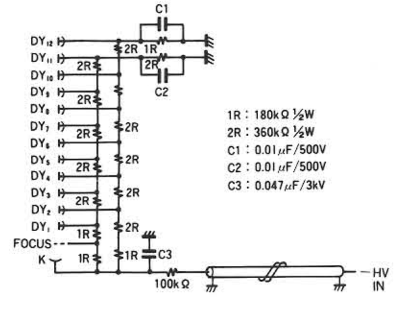
R2487-02





Crossed Wire Anodes





Photomultiplier Tube Assemblies

(For further information, a technical data sheet is available.)

Hamamatsu offers a variety of integral assemblies of tubes, sockets, voltage dividers and magnetic shields. These photomultiplier tube assemblies can be operated by simply supplying an optimum high voltage.

Head-On PMT Assemblies

Type No.	H3164	H3165	H1051	H3167	H3171	H1161	H1949	H2431	H2520	R1250-03
Bulit-in PMT	R1635	R647	R1166	R1450	R3082	R329-01	R1828-01	R2083	R2490	R1250
Operationg Supply Voltage (V)	−1250	−1000	−1000	−1500	−1250	−2000	−2500	−3000	−2500	−2500
Operating Supply Current (μA)	340	1000	90	400	430	910	1200	520	300	1610
Output Impedance (Ω)	50	50	OPEN	50	50	OPEN	OPEN	OPEN	OPEN	OPEN
Dimensions (dia. × L mm) Ⓐ	φ11×95	φ15.2×116	φ24.1×114	φ24.6×140	φ33×141	φ60×215	φ60×235	φ53×200	φ60×155	φ142×360

Ⓐ Excluding connectors

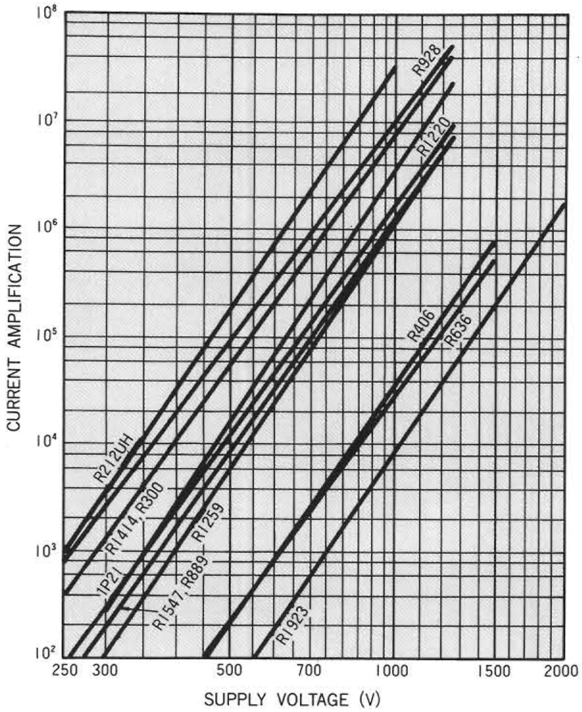
Side-On PMT Assemblies with Built-in DC-DC Converter Type Power Supply

Type No.	H957-01	H957-06	H957-08
Built-in PMT	R212	931B	R928
Input Voltage Range (V)	+15 ±0.5		
Maximum Input Current (mA)	150		
Output Voltage Range (V)	−400V ~ −900 V		
Output Voltage Programming	Resistance (0 ~ 10 kΩ) or Voltage (0 ~ 4 V) Programming		
Dimensions (dia. × L mm)	φ32 × 100		

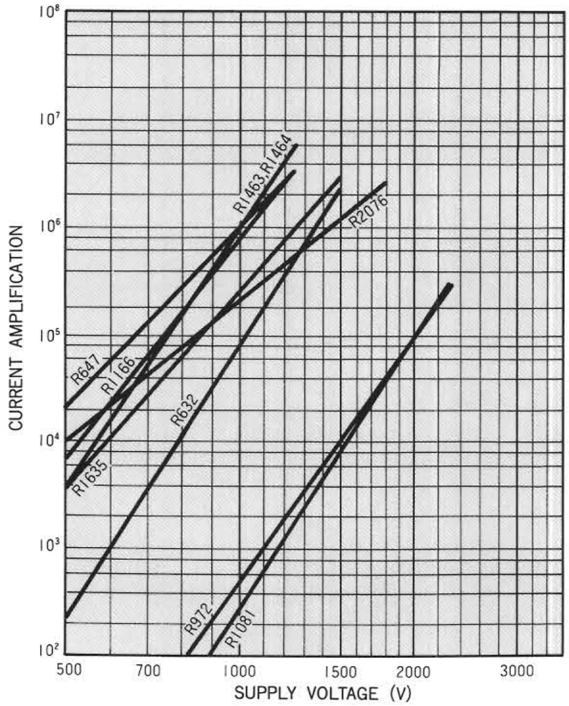
Current Amplification Characteristics

(For tubes not listed here, please consult our sales office)

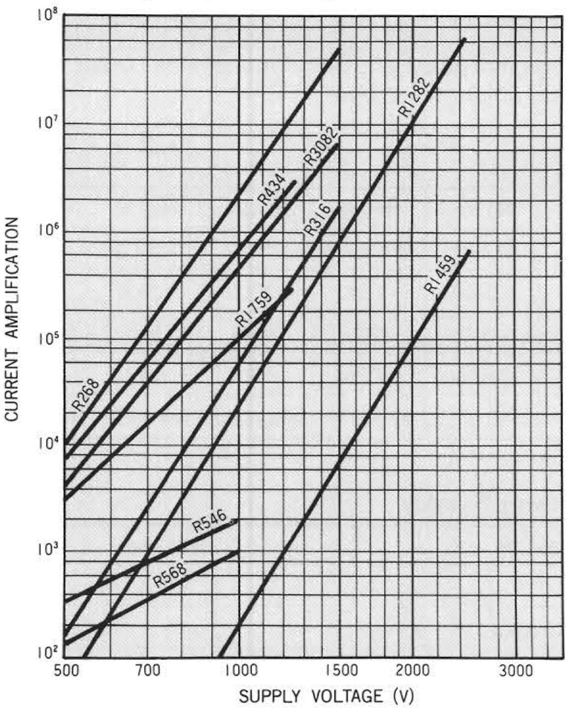
● **Side-On Types**



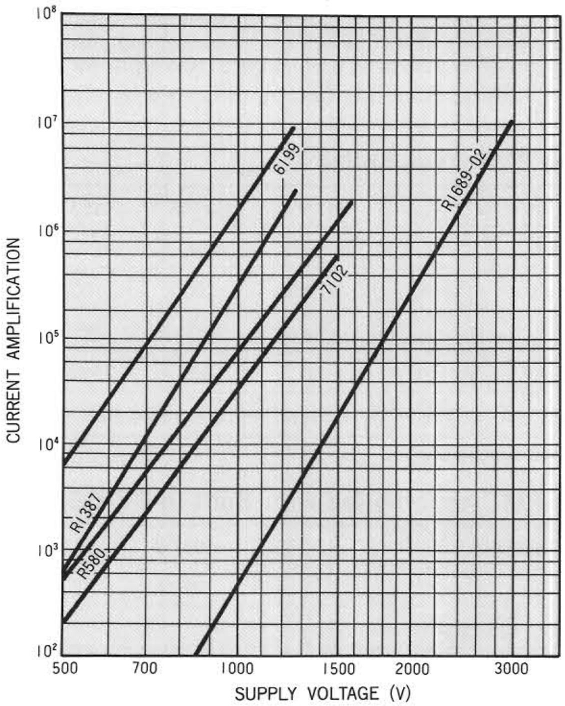
● **Head-On Types (3/8" ~ 1" Dia.)**



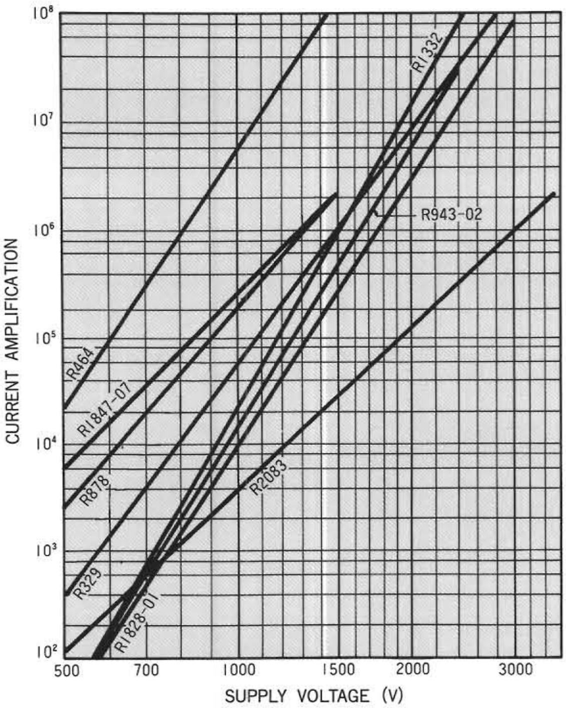
● **Head-On Types (1-1/8" Dia.)**



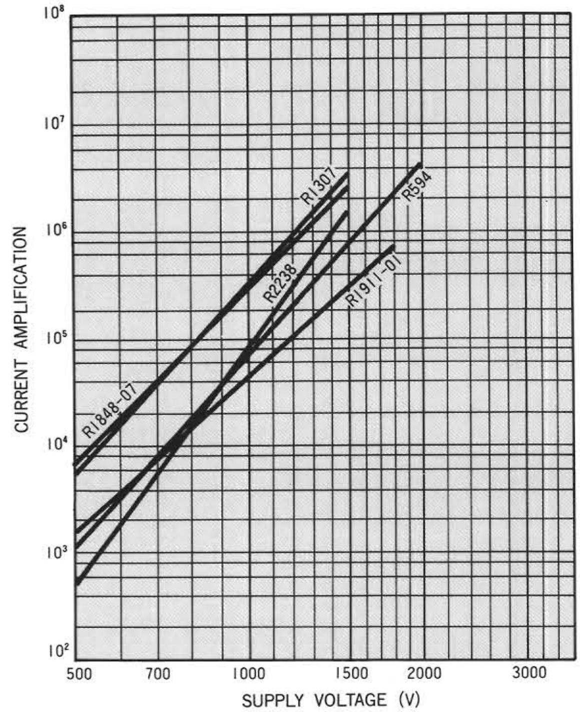
● **Head-On Types (1-3/8", 1-1/2" Dia.)**



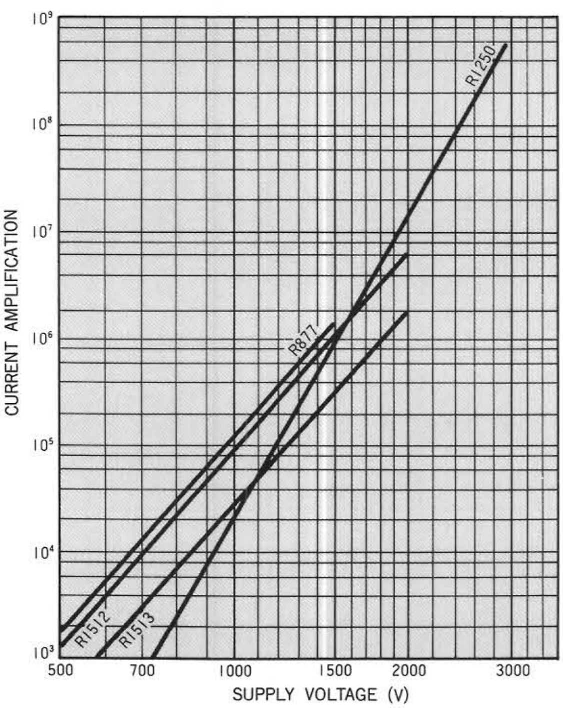
● **Head-On Types (2" Dia.)**



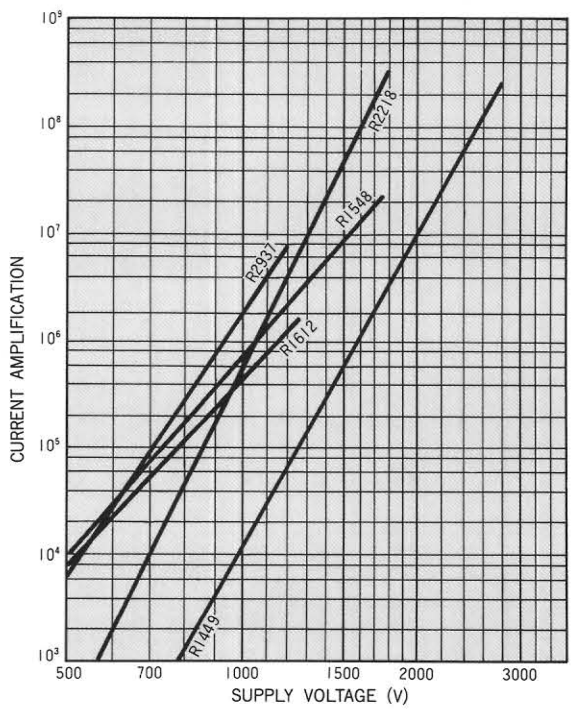
● **Head-On Types (3" Dia.)**



● **Head-On Types (5" Dia.)**



● **Hemispherical and Special Envelope Types**



Voltage Distribution Ratio

The characteristic values tabulated in this catalog for the individual tube types are measured with the voltage-divider networks having the voltage distribution ratio shown below.

Distribution Ratio Codes	Number of Stage	Voltage Distribution Ratio K: Photocathode Dy: Dynode P: Anode G: Grid																	
	4	K	Dy1	Dy2	Dy3	Dy4	P												
①		1	1	1	1	1													
	5	K	Dy1	Dy2	Dy3	Dy4	Dy5	P											
②		1	1	1	1	1	1												
	6	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	P									
③		2	2	1	1	1.5	2.4	4.4	5.6										
	7	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	P								
④		1	—	1	1	1	1	1	1	1									
	8	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Acc	Dy7	Dy8	P						
⑤		2	—	2	1	1	1	1	1	—	1	1							
⑥		1	1	1	1	1	1	1	1	—	1	1							
⑦		1.3	4.8	1.2	1.8	1	1	1	1	0.5	3	2.5							
⑧		3	—	1.5	1	1	1	1	1	—	1	1							
⑨		7	—	1	1.5	1	1	1	1	—	1	1							
	9	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P							
⑩		1	1	1	1	1	1	1	1	1	1								
	10	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P					
⑪		1	—	1	1	1	1	1	1	1	1	1	1						
⑫		1	1	1	1	1	1	1	1	1	1	1	1						
⑬		1.5	—	1	1	1	1	1	1	1	1	1	1						
⑭		2	—	1	1	1	1	1	1	1	1	1	1						
⑮		2	—	1	1.5	1	1	1	1	1	1	1	0.75						
⑯		2	2	1	1	1	1	1.5	2	3	4.3	5	6.2						
⑰		3	—	1	1	1	1	1	1	1	1	1	1						
⑱		3	—	1	1.5	1	1	1	1	1	1	1	1						
⑲		3	—	1.5	1	1	1	1	1	1	1	1	1						
⑳		4	—	1	1.5	1	1	1	1	1	1	1	1						
㉑		6	—	1	1.5	1	1	1	1	1	1	1	1						
	11	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P				
㉒		1	—	1	1	1	1	1	1	1	1	1	1	1					
	12	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	P			
㉓		1	1	1	1	1	1	1	1	1	1	1	1	1	1				
㉔		1.2	2.8	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5				
㉕		2	—	1	1	1	1	1	1	1	1	1	1	1	1				
㉖		4	0	1	1.4	1	1	1	1	1	1	1	1	1	1	(Note 1)			
㉗		4	0	2.5	1.5	1	1	1	1	1	1	1	1	1	1				
㉘		6	0	1	1.4	1	1	1	1	1	1	1	1	1	1	(Note 1)			
	13	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy11	Dy12	Dy13	P				
㉙		8	0	1	1	1	1	1	1	1	1	1	1	1					
	14	K	G1	G2	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
㉚		2.5	7.5	0	1.2	1.8	1	1	1	1	1	1	1	1	1.5	1.5	3	2.5	
	16	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	Dy16	P
㉛		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

Note 1. The shield pin should be connected to Dy5 except R1017.

Replacement Information

*: The same dimensional outline, base connection and electric characteristics.
**: The similar electric characteristics and the same dimensional outline and base connection.
***: The similar electric but different dimensional outline and/or different base connection.

RCA	Hamamatsu
Side-On Types	
931A	931A*
931B	931B* R105**
4473	R372**
4526	R1923*
4552	R906*
4832	R636* R666**
4840	R446*
8571	R1414***R300***R2371***
1P21	1P21* R105** R105UH**
1P28	1P28*
1P28/V1	R212* 1P28**
1P28A	1P28A*
1P28A/V1	R372**
1P28B	R1516*
C31004, C31004A	R406*
Head-On Types	
4440	R980***6199***
4463	R550**PM55**
4465	R1513*
4501/V3, 4501/V4	R331-05* R331**
4507	R331-05**
4516	R1213*** R1166***
4517	R980*
4518	R878**
5425	R1512*
4855	R580*
4900	R594***
4903	R1387*
6199	6199**
6342A	7696**
6655A	7696**
7102	7102*
7767	R1213*** R1166***
8053	R878**
8054	R594**
8055	R1512**
8575	R329*
8644	R1464***
8850	R1332*
8852	R1333*
C31000A	R1017**
C3100AJ	R1640**
C31005	R821***
C31007B	6199**
C31016G	R1288*
C31016F	R1924-01**
C31034	R943-02***
C31053A	R594**
C31059	R268*
C31059A	R1282*
C31059B	R374** R1104**
C70042K	R1464***
C70042Y	R1166***
C70102B	R632***

EMI	Hamamatsu
Side-On Types	
9661B	1P28*
9665B	R106*
9781B	1P28* R212**
9781R	1P28A*
9781RA	R905* R372**
9783B	R106*
9785B	R446* R928**
9785QB	R456* R955**
9786B	R446**
9786QB	R456**
Head-On Types	
6097B	7696***
9524B,9824B,9924B	R268**
9256B	7679***
9526B	R292**
9530KB, 9530KR	R877***
9558QB	R562*
9633KB	6199* R980**
9635B	R2014**
9635QB	R2014**
9656KB	7696*
9656KL, 9656KR	R878**
9659B	R669***
9698B	R374**
9698QB	R376*
9734B	R434*
9734QB	R292***
9757B, 9957B	R878***
9758KB, 9758B	R594***
9791B	R877***
9790B	R1513***
9798B	R1104**R374**R453**
9798QB	R376**
9805K	R878*
9811B	R329***
9814B	R329***
9817B	R1017***
9822KB, 9822B	R594***
9824QB, 9924QB	R292*
9825B	R1166***
9826B	R268*
9829B	R331-05*
9829Q	R331*
9856KB	R878***
9856, 9956	R878***

Philips	Hamamatsu
56DVP	R1828-01***
58DVP	R1250**
150AVP	R580**
150CVP	7102***
153AVP	R878**
PM1910	R1450**
XP-1000	7696* R878**
XP-1001	R878**
XP-1002	PM55** R550**
XP-1003	PM55**
XP-1004	R208*
XP-1006	R878*
XP-1010	R580*
XP-1011	R580**
XP-1030	R594**
XP-1031	R594**
XP-1034	R594*
XP-1110	R1213* R1166**
XP-1116	R632***
XP-1230	R331-05* R331**
XP-1911	R1166* R1213* R1450*
XP-2020	R1828-01**
XP-2202B	7696***R878***R2154**
XP-2312B	R594***
XP-2412B	R594***

DuMont	Hamamatsu
6921	R580**
6292	7696**
6364	R877**
7064	7696*
7664	R208*
8055	R877*
DM3112	R580*
DM3123	R268**
DM3126R	R376**
DM3159	R878*
K2251	R580**
KM2433	R550* PM55*
KM2520	R878*
KM2536	R877*
KM2544	R594*
KM2675	R580*
KM2703	R375***
KM2800	R669***

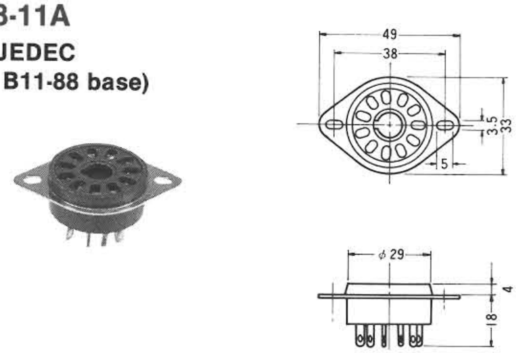
Hamamatsu Types To Be Replaced

Types listed in the previous catalog but not in this catalog	Hamamamtsu replacement types
R761-01	R1463-01**
R1194U	R1644U***
R1770	R2937***
R1294U	R1645U***
R712	R2228**
R1668	R3172**
R1398	R3082**

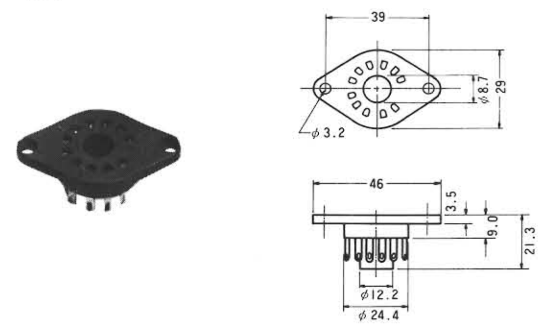
ACCESSORIES FOR PHOTOMULTIPLIER TUBES

E678 Series Sockets

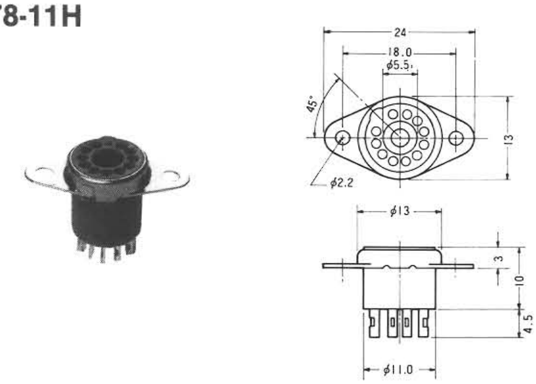
E678-11A
(For JEDEC No. B11-88 base)



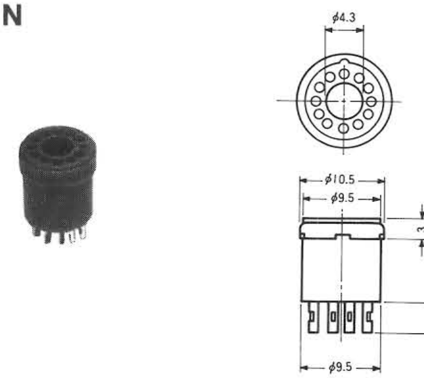
E678-11C



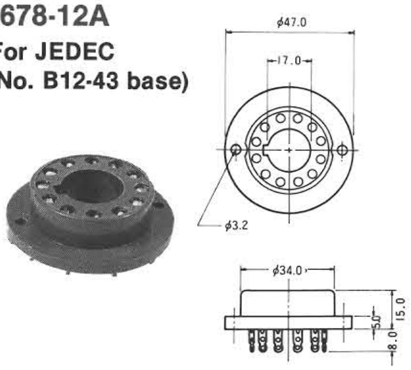
E678-11H



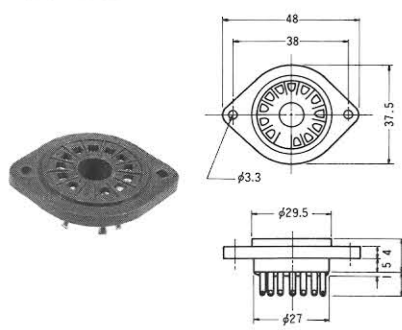
E678-11N



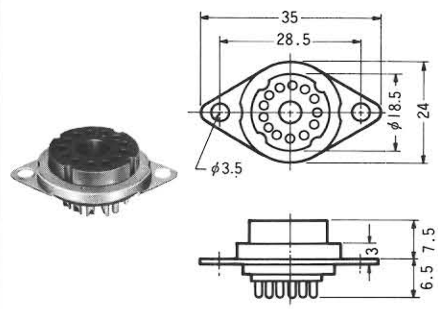
E678-12A
(For JEDEC No. B12-43 base)



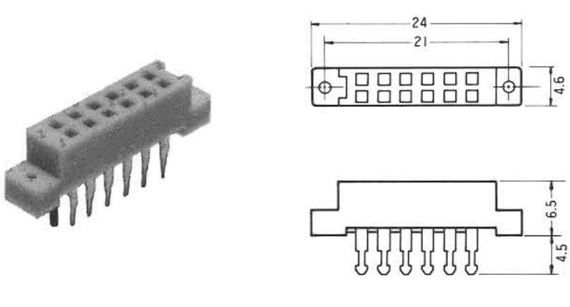
E678-12C



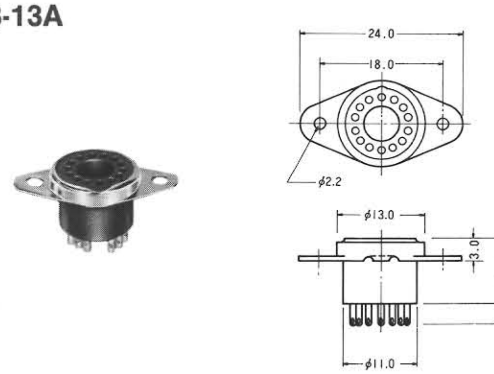
E678-12D



E678-12E

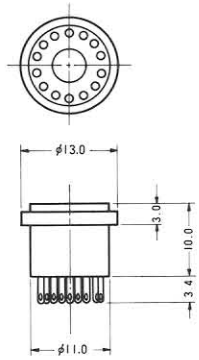


E678-13A

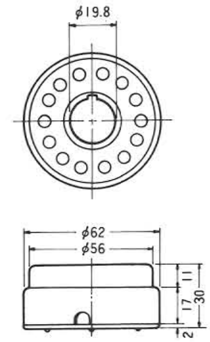


Unit: mm

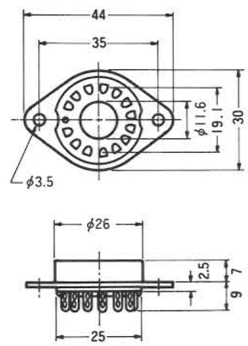
E678-13D

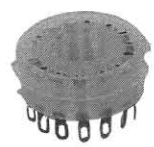
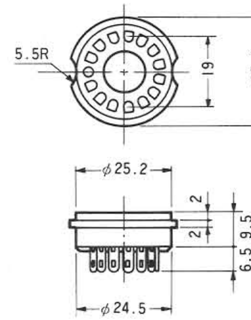
E678-14A
(For JEDEC No.B14-38 base)

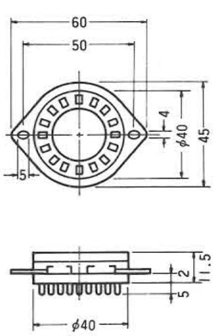
E678-14C

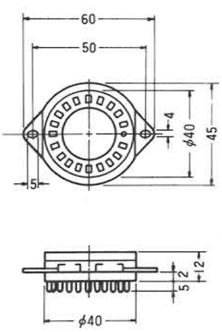
E678-14H

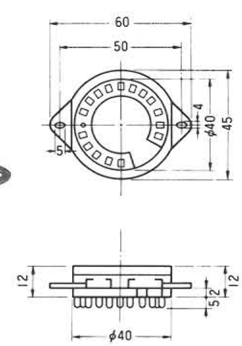
E678-15A

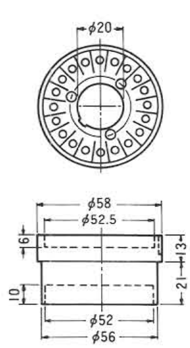
E678-19A

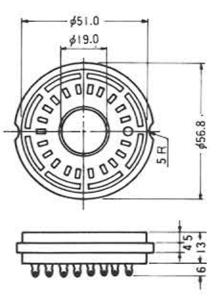
E678-19C

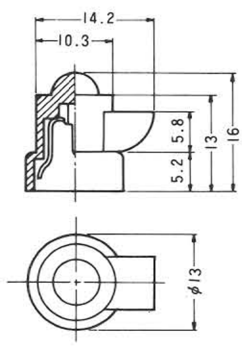
E678-20A
(For JEDEC No.B20-102 base)

E678-21A

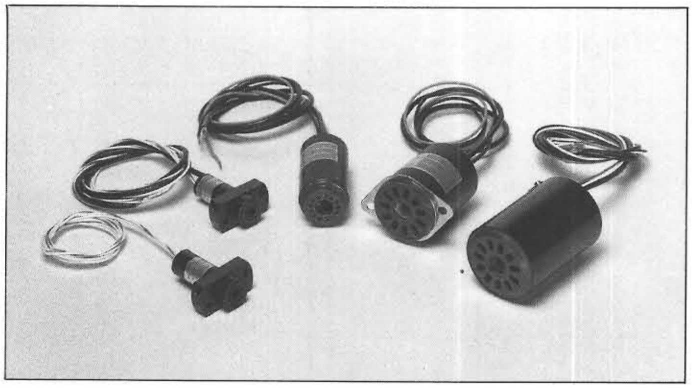
E678-1B
(For C1-2 cap terminal)

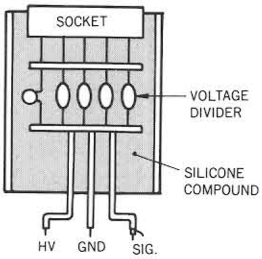
Socket Assemblies (For further information, a detailed catalog is available.)

Hamamatsu sells a complete line of compact socket assemblies which are engineered to educe the maximum performance from the photomultiplier tubes while imposing minimum wiring tasks on the users. Tight potting of the voltage divider and other circuits using carefully selected silicone compound ensure the reliability of the unit against humidity and other harsh environments.

The socket assemblies are classified into three types by their functions as described below.



■ D Type Socket Assemblies



The D type socket assemblies incorporate a voltage divider circuit. A high voltage power supply and a current/electric charge signal processing circuit are required. Four types are available according to the ground electrode, supply voltage polarity and output signal form.

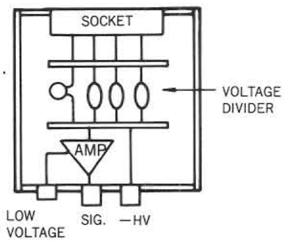
PMT Diameter mm (inches)		No. of Stages	Applicable PMT Type No.	Ground Electrode/ Polarity of Supply Voltage	Output Signal	Socket Assembly Type No.
Head-on	7 × 24	10	R2937, etc.	Anode/−	DC/Pulse	E2379
	10 (3/8")	8	R1635, R1893, R1894, R2055, etc.	Anode/−	DC	E1761-03
					DC/Pulse	E1761-04
	13 (1/2")	10	R647, R759, R760, R1463, R2077, etc.	Anode/−	DC	E849-34
					DC/Pulse	E849-35
				Anode/− or Cathode/+	DC/Pulse	E849-36
	19 (3/4")	10	R632, R750, R821, R1166, R1464, R1617, etc.	Anode/−	DC/Pulse	E974-13
	28 (1-1/8")	11	R268, R292, R316, R374, R431S, R376, R712, R1104, etc.	Anode/−	DC/Pulse	E990-07
				Cathode/+	Pulse	E990-08
	38 (1-1/2")	10	6199, 7102, R189, R580 R980, R1387, R1508, etc.	Anode/−	DC/Pulse	E2183
				Cathode/+	Pulse	E2183-02
	51 (2")	10	7696, PM55, R208, R550, R878, R1507, etc.	Anode/−	DC/Pulse	E1198-03
				Cathode/+	Pulse	E1198-04
			R375, R669, etc.	Anode/−	DC/Pulse	E1435
		12	R329, R331, R1221, etc.	Anode/−	Pulse	E934*
			R1332, R1333, etc.	Anode/−	DC/Pulse	E2380
			R943-02, etc.	Anode/−	DC/Pulse	E2380-01
	76 (3")	10	R594, R1511, etc.	Anode/−	DC/Pulse	E1198-03
				Cathode/+	Pulse	E1198-04
	127 (5")	10	R877, R1512, R1513, etc.	Anode/−	DC/Pulse	E1198-03
				Cathode/+	Pulse	E1198-04

*E934 is designed for high-speed and high-current pulsed applications and is furnished with a special magnetic shield case.

(D Type Socket Assemblies cont'd)

PMT Diameter mm (inches)		No. of Stages	Applicable PMT Type No.	Ground Electrode/ Polarity of Supply Voltage	Output Signal	Socket Assembly Type No.
Side-on	13 (1/2")	9	R1413, R1414, R1546, R1547, R1657, etc.	Anode/−	DC	E850-12
					DC/Pulse	E850-13
	13 (1/2") with anode cap	9	R300, R306, R427, R444, R500, R889, R1503, etc.	Anode/−	DC	E657
				Anode/− or Cathode/+	DC/Pulse	E657-03
	28 (1-1/8")	9	931A, R105, R106, R166, R212, R446, R636, R928, R1516, etc.	Anode/−	DC/Pulse	E717-21
				Anode/− or Cathode/+	DC/Pulse	E717-35

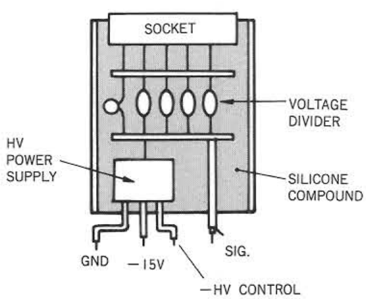
■ DA Type Socket Assemblies



The DA type socket assemblies incorporate a current to voltage conversion amplifier in addition to a voltage divider circuit. High voltage (for PMT) and low voltage (for amp.) power supplies are required. Since the high impedance output of the photomultiplier tube is connected to the amplifier at a minimum distance, the problem of external noise induced in connecting cables can be eliminated.
In addition, the C1053-03 and C1556-03 which are BNC connector input type amplifiers are available.

Type No.	Applicable PMT	Divider Circuit Supply Voltage	Input Voltage for Amp.	Current to Voltage Conversion Factor	Maximum Output Voltage	Frequency Bandwidth
C1053	28 mm (1-1/8") Head-on	−1500 Vdc Max.	± 12 ~ ± 15 Vdc	0.3 V/μA	2 Vp (at 5MHz) 10 Vp (at 2.5MHz)	DC to 5 MHz
C1053-01	28 mm (1-1/8") Side-on					
C1053-03	BNC connector input	Not included				
C1556	28 mm (1-1/8") Head-on	−1500 Vdc Max.			10 Vp (at 10kHz)	DC to 10 kHz
C1556-01	28 mm (1-1/8") Side-on					
C1556-03	BNC connector input	Not included				

■ DP Type Socket Assemblies (for 1-1/8" Side-On PMT)

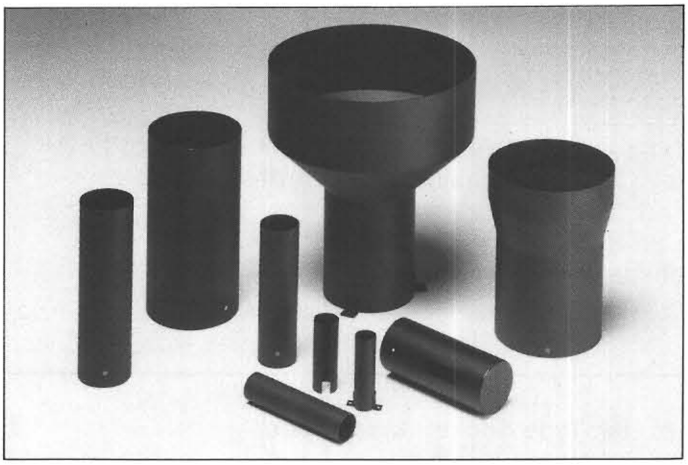


The DP type socket assemblies feature a built-in voltage divider and DC-DC converter type high-voltage power supply. By applying a +15 V supply, easy operation of PMT is possible. A current/electric charge signal processing circuit is required.

Type No.	Applicable PMT	Input Voltage Range	Input Current	Output Voltage Range	Drift	Maximum PMT Output at 900V	Dimensions
C956-04	28 mm (1-1/8") dia. Side-on	+15 ± 1 Vdc	150 mA max.	−400 ~ −900 Vdc	± 0.05%/h Max. (after 15 min.)	15 μAdc, 1.5 mAp (f = 1kHz, t_w = 1μs)	35 dia. × 76 mm
C956-05							35 dia. × 50 mm
C956-06			120 mA max.	−200 ~ −1250Vdc			35 dia. × 76 mm

Magnetic Shield Cases

Photomultiplier tubes are generally very susceptible to magnetic fields, which normally decrease the gain of the tube. It is, therefore, necessary to cover the tube with a magnetic shield case to minimize the magnetic effect when the tube is located in the neighborhood of a transformer or other intense magnetic field sources. Hamamatsu E989 series magnetic shield cases are made of permalloy which has high permeability, and are suitable for most commercially available photomultiplier tubes.



PMT Diameter		Magnetic Shield Case Type No.	Inside Diameter (mm)	Thickness (mm)	Length (mm)	Weight (g)
Side-on	13 mm (1/2")	**E989-10**	14.5	0.5 ± 0.1	47 ± 0.5	10
	28 mm (1-1/8")	**E989**	33.6 ± 0.8	0.8 ± 0.1	80 ± 1	66
Head-on	10 mm (3/8")	**E989-28**	12 ± 0.3	0.5 ± 0.1	48 ± 0.5	9
	13 mm (1/2")	**E989-09**	16 ± 0.8	0.8 ± 0.1	75 ± 0.5	28
	19 mm (3/4")	**E989-02**	23 ± 0.8	0.8 ± 0.1	95 ± 1	50
	28 mm (1-1/8")	**E989-03**	32 ± 0.8	0.8 ± 0.1	120 ± 1	90
	38 mm (1-1/2")	**E989-04**	$44 \pm^{1}_{0}$	0.8 ± 0.1	100 ± 1	102
	51 mm (2")	**E989-05**	$60 \pm^{1}_{0}$	0.8 ± 0.1	130 ± 1	180
	76 mm (3")	**E989-15**	81 ± 1	0.8 ± 0.1	120 ± 1	200
	127 mm (5")	**E989-26**	138.4 ± 1	0.8 ± 0.1	170 ± 1	600

Thermoelectric Coolers

The thermionic electron emission from the photocathode generally predominates over the electrical leakage or other factors which constitute the dark current of the photomultiplier tube. It is possible to reduce the dark current and improve the detectivity of the tube by cooling the photocathode. Hamamatsu provides a variety of thermoelectric coolers specifically designed for photomultiplier tubes.

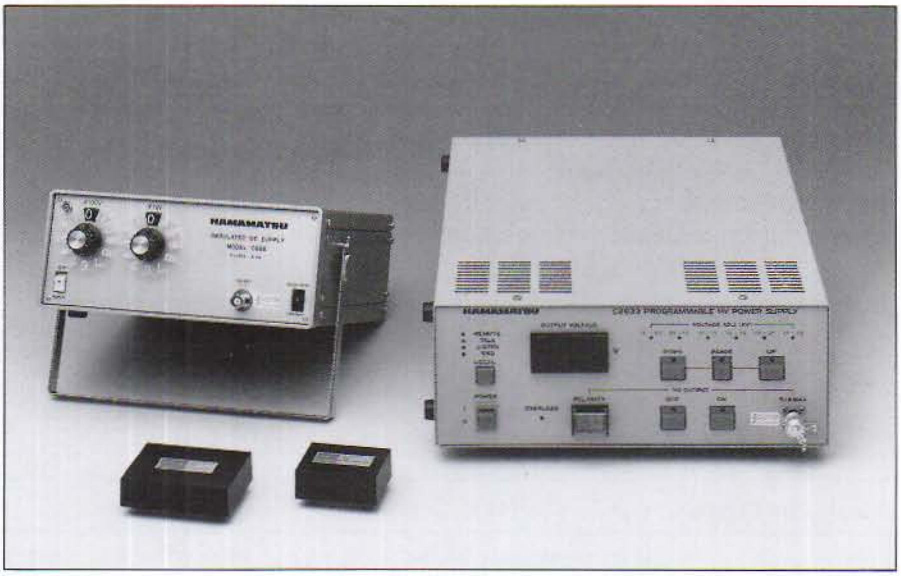
▲ C2761

Type No.	Applicable PMT	Cooling Temp. *	Remarks
C659S	1-1/8" Dia. Side-On	−15°C	
C659B	1-1/8", 1-1/2" Dia. Head-On	−20°C	
C2761	1-1/2", 2" Dia. Head-On	below −30°C	Temperature controllable
C2773	MCP-PMT	below −30°C	Temperature controllable

* at +20°C water coolant

Regulated High-Voltage Power Supplies

The output of a photomultiplier tube is extremely sensitive to the applied voltage. Even small variations in applied voltage greatly affect measurement accuracy. Thus a highly stable source of high voltage is required. Hamamatsu regulated high-voltage power supplies are designed for precision measurement and available in various configurations and performances, including modular types for PC board mounting, bench top types and a −5 kV output type for MCP-PMTs.



Configuration	Type No.	Remarks	Output Polarity	Output Voltage Range	Max. Output Current	Input Voltage
Modular Type	C2456	Very small size	−	−190 ~ −1100 Vdc	0.5 mA	+15 Vdc
	C1309-01	Large current output	−	−400 ~ −800 Vdc	2 mA	
	C1309-02	General purpose	−	−200 ~ −1100 Vdc	0.5 mA	
	C1309-04	High stability	−	−200 ~ −1100 Vdc	0.5 mA	
	C1309-06	High voltage output	−	−400 ~ −1500 Vdc	1 mA	
Bench-Top Type	C665	Portable, high stability	−	−200 ~ −1190 Vdc	5 mA	Specify your line voltage at ordering
	C448A	High current output	+ / −	±250 ~ ±1500 Vdc	15 mA	
	C752-01	High voltage output	+ / −	±500 ~ ±2500 Vdc	5 mA	
	C2230	High voltage output	+ / −	±250 ~ ±3000 Vdc	5 mA	
	C2633	Computer programmable	+ / −	±200 ~ ±3071 Vdc	5 mA	
	C2356	Very high output voltage, For MCP-PMT, etc.	−	−1000 ~ −5000 Vdc	0.5 mA	

Photon Counters and Related Products

Photon counting has become widely used as a method of light detection at very low-light levels. As a leading manufacturer of photomultiplier tubes, Hamamatsu provides photon counters and related products. For further information, please feel free to contact Hamamatsu sales offices.

ELECTRON MULTIPLIERS

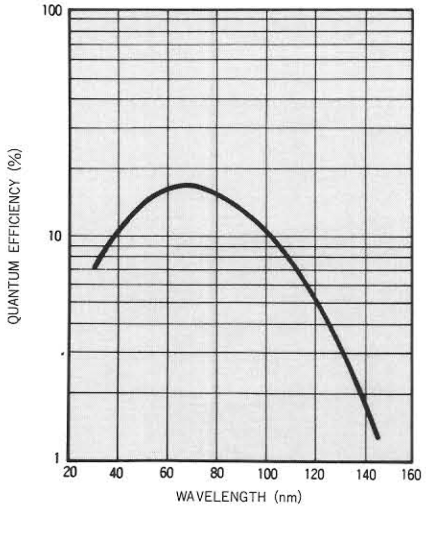
Electron multipliers (also called ion multipliers) are specially designed for the detection and measurement of electrons, charged particles such as ions, vacuum UV radiations and soft X-rays. Hamamatsu electron multipliers have high gain and low noise, making them suitable for the detection of very small or low energy particles by using the counting method. They are well suited for mass spectroscopy, field ion microscopy, and electron spectroscopy such as AES and ESCA.

A variety of electron multipliers is available in head-on or side-on viewing configuration. Each type has Cu-BeO dynodes connected by built-on divider resistors (1 MΩ per stage) and is supplied in an evacuated glass bulb. The first dynode can be replaced by a photocathode of Cs-I, K-Br, etc.

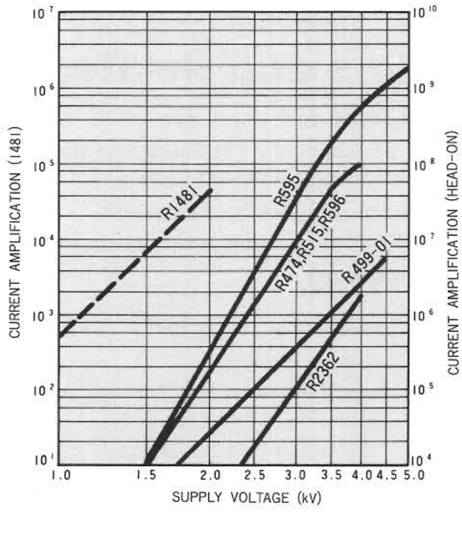
Type No.	Outline	Dynode: Number of Stages	Dynode: Structure	Dynode: Material	Dynode: Radiation Opening (mm)	Characteristics: Supply Voltage (Vdc)	Characteristics: Current Amplification Typ.	Characteristics: Rise Time Typ. (ns)	Anode to All Other Electrode Capacitance (pF)	Maximum Ratings: Anode to First Dynode Voltage (Vdc)	Maximum Ratings: Anode to Last Dynode Voltage (Vdc)	Maximum Ratings: Ⓐ Average Anode Current (μA)	Maximum Ratings: Operating Vacuum Level (torr)
Head-On Types													
R474	1	16	Box-and-Grid	Cu-BeO	8 × 6	2400	1×10^6	9.3	5.0	4000	350	10	1×10^{-4}
R515	2	16	Box-and-Grid	Cu-BeO	8 × 6	2400	1×10^6	9.3	4.0	4000	350	10	1×10^{-4}
R596	3	16	Box-and-Grid	Cu-BeO	12 × 10	2400	1×10^6	10	9.0	4000	400	10	1×10^{-4}
R595	4	20	Box-and-Grid	Cu-BeO	12 × 10	3000	4×10^7	12	9.0	5000	400	10	1×10^{-4}
R499-01	5	18	Venetian Blind	Cu-BeO	16 × 16	2700	1.8×10^5	—	6.5	4500	400	10	1×10^{-4}
*R2362	7	23	Mesh	Cu-BeO	20 dia.	3450	5.0×10^5	3.5	23	4000	350	10	1×10^{-4}
Side-On Type													
R1481	8	10	Circular-Cage	Cu-BeO	4 × 13	1500	1.0×10^3	—	2.0	2000	200	2	1×10^{-4}

Ⓐ: Averaged over any interval of 30 seconds maximum.
*: Types with large radiation opening of 58 mm and 105 mm in diameter are also available.

● Typical Spectral Response of Cu-BeO Used for Dynodes

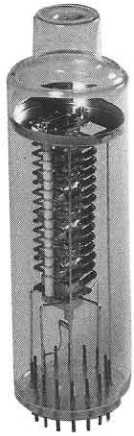


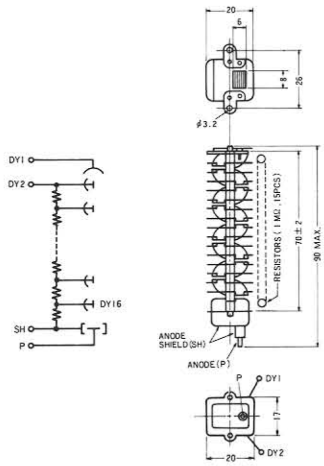
● Typical Current Amplification



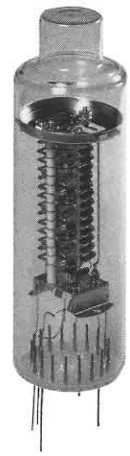
Unit mm

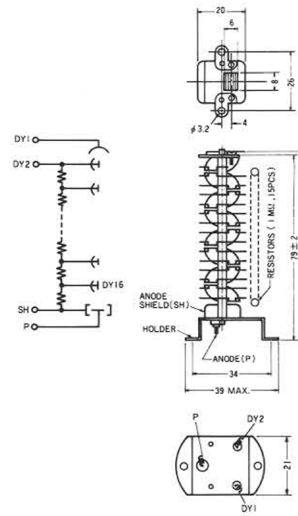
❶ R474



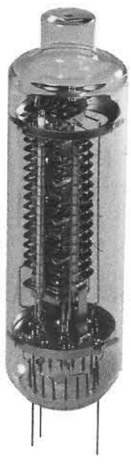


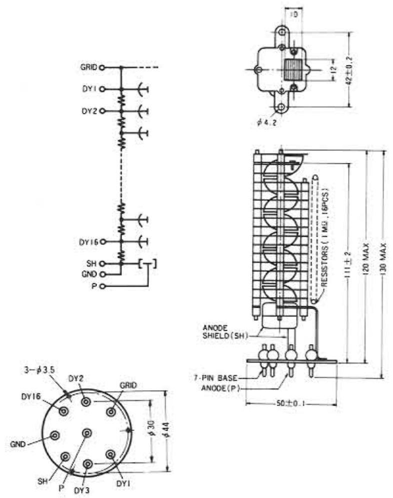
❷ R515





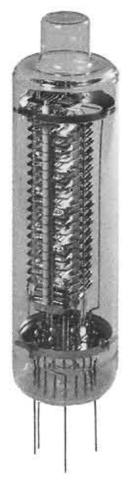
❸ R596

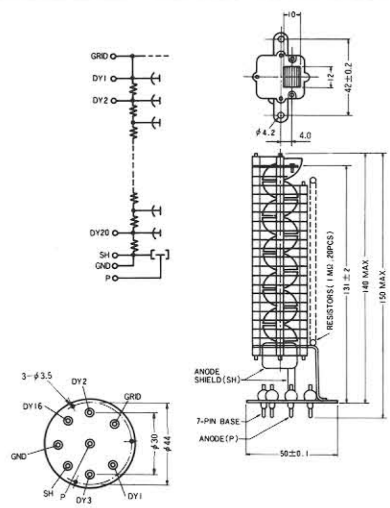




(Socket E678-7B is supplied with tube.)

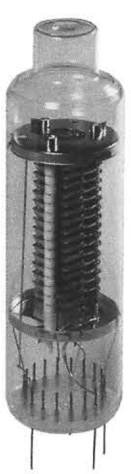
❹ R595

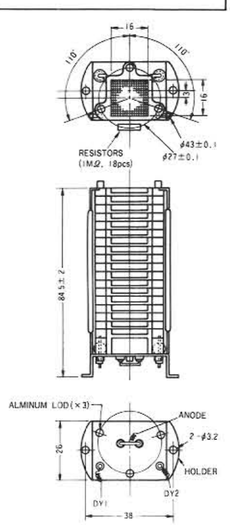




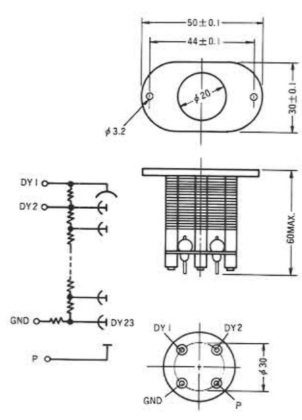
(Socket E678-7B is supplied with tube.)

❺ R499-01

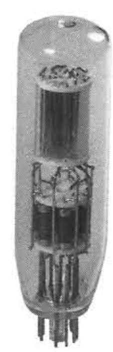


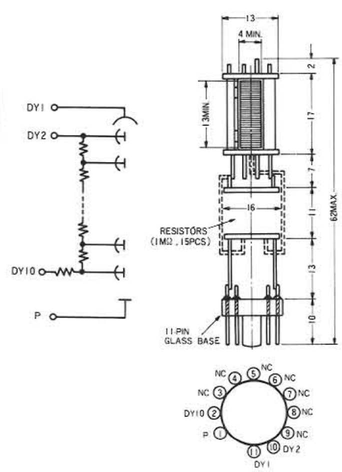


❻ R2362



❼ R1481





MICROCHANNEL PLATES

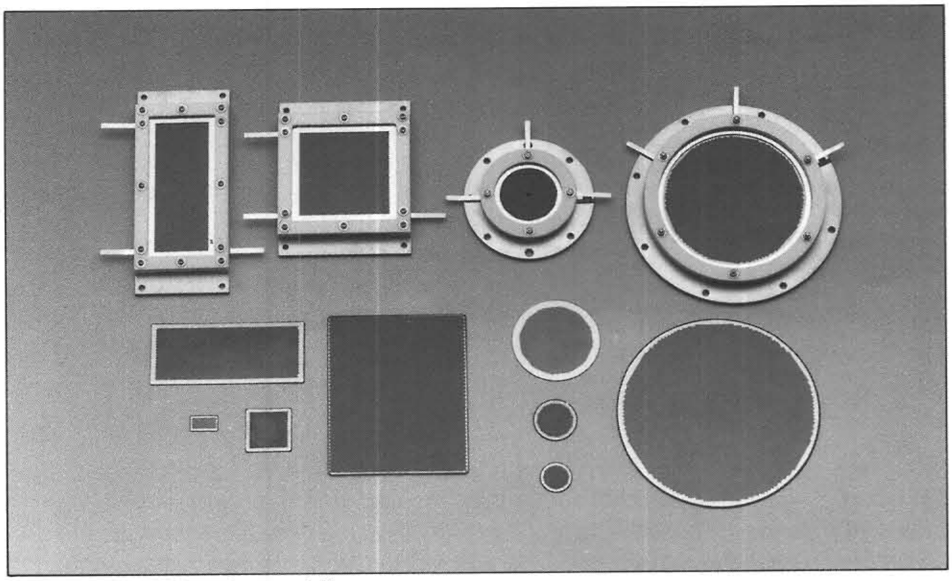
(For further information, technical data sheets are available.)

A microchannel plate (MCP) is a secondary electron multiplier consisting of array of millions of glass capillaries (channels) fused in the form of a thin plate. Each channel has an internal diameter ranging from 10 µm to 25 µm and is coated with a secondary electron emissive material, thus each channel becomes an independent electron multiplier. MCP is also sensitive to charged particles, UV radiations and X-rays. Major features of MCP include high gain, 2-dimensional detection, fast response, immunity to magnetic fields and small size.

In addition to types listed below, Hamamatsu also provides a variety of MCP assemblies including single-, two- and three-stage MCP with necessary leads and output devices.

Type No. (A)	Dimension: Outer Diameter (mm)	Dimension: Effective Diameter (mm)	Dimension: Channel Diameter (µm)	Dimension: Bias Angle (°)	Dimension: Open Area Ratio (%)	Electrode Material	Characteristics (B): Minimum Current Gain	Characteristics (B): Plate Resistance (MΩ)	Characteristics (B): Dark Current (A/cm²)	Characteristics (B): Maximum Linear Output Signal (C)	Maximum Ratings: Supply Voltage (V) (D)	Maximum Ratings: Ambient Temperature (°C)
3/4 inch (18 mm) Dia. Types												
F1551-01	18	14.5	12	8	57	Inconel or Ni-Cr	10^4	100 ~ 1000	5×10^{-13}	7% of strip current	1000	−50 ~ +70
F1551-03			20								1200	
1 inch (25 mm) Dia. Types												
*F1094-09	24.9	20.0	10	5	57	Inconel or Ni-Cr	10^4	100 ~ 700	5×10^{-13}	7% of strip current	1000	−50 ~ +70
F1094-01			12	5, 8, 15								
F1094-03			20	8							1200	
1-1/4 inch (33 mm) Dia. Types												
*F1552-09	32.8	27.0	10	12	57	Inconel or Ni-Cr	10^4	30 ~ 300	5×10^{-13}	7% of strip current	1000	−50 ~ +70
F1552-01			12									
F1552-03			20	8							1200	
1.5 inch (38 mm) Dia. Types												
F1208-01	38.5	32.0	12	8	57	Inconel or Ni-Cr	10^4	20 ~ 300	5×10^{-13}	7% of strip current	1000	−50 ~ +70
F1208-03			20								1200	
2 inch (50 mm) Dia. Types												
F1217-01	50.0	42.0	12	5, 8	57	Inconel or Ni-Cr	10^4	10 ~ 200	5×10^{-13}	7% of strip current	1000	−50 ~ +70
F1217-03			20	8							1200	
3.4 inch (50 mm) Dia. Type												
*F1942-04	86.7	77.0	25	8	57	Inconel or Ni-Cr	10^4	10 ~ 100	5×10^{-13}	7% of strip current	1200	−50 ~ +70
4.5 inch (114 mm) Dia. Type												
*F2395-04	114	105	25	8	57	Inconel or Ni-Cr	10^4	5 ~ 500	5×10^{-13}	7% of strip current	1200	−50 ~ +30
Rectangular Types												
*F2370-01	16 × 9.5	13 × 6.5	12	8	57	Inconel	10^4	300	5×13^{-13}	7% of strip current	1000	−50 ~ +70
*F2807-01	62 × 10	55 × 8						80				
*F1948-01	25 × 25	21 × 21										
*F2806-01	50 × 40	45 × 35						60				
*F2805-02	60 × 60	53 × 53	15					20			1100	
*F1943-02	88 × 38	81 × 31										
*F2396-04	97 × 79	94 × 76	25	19				10			1200	

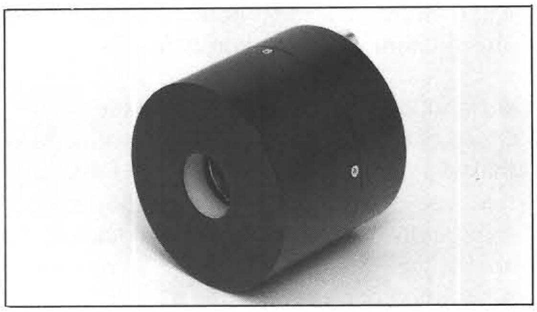
(A) *: Newly listed in this catalog.
(B) At 1000V, 1×10^{-6} torr, 25°C
(C) Strip current is given by: Applied voltage divided by plate resistance.
(D) At 1×10^{-6} torr or less.



A variety of MCP and assemblies

Examples of Products Using MCP

MCP-PMTs

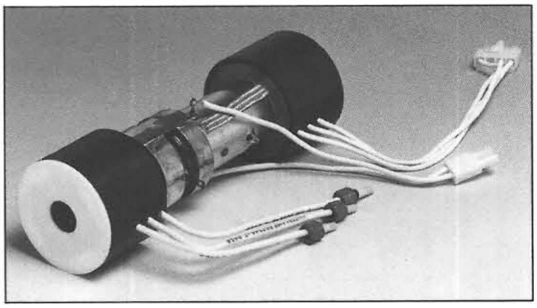


Owing to superior time response and detectivity at low-light levels, MCP-PMTs are useful photodetectors in the fields using lasers. Especially, MCP-PMTs are very effective in time-correlated photon counting which is widely used for biological science and material engineering. (See page 54.) A technical data sheet is available upon request.

Image Intensifiers

The image intensifier incorporates an MCP which is capable of image intensification of more than 10,000 times. It is widely used in night vision devices, and also its use is spreading to scientific and measurement applications such as astronomical observation, nocturnal animal studies, microscopy, and spectroscopy. A detailed catalog is available from our sales office.

Streak Tubes



The streak tube is an ultra-high-speed photodetector that can capture an ultra-short phenomenon in the order of picoseconds. It provides not only temporal information, but also one-dimensional spatial information. Hamamatsu streak tubes include an MCP which allows high sensitivity.

Cautions

HIGH VOLTAGE WARNING

Photomultiplier Tubes, Electron Multipliers, Microchannel Plates, High Voltage Power Supplies.
The high voltage used by these devices may present a shock hazard. They should be installed and handled only by qualified personnel that have been instructed in handling of high voltage. Designs of equipment utilizing these devices should incorporate appropriate interlocks to protect the operator and service personnel.

PRECAUTIONS FOR USE

● Handle tubes with extreme care
Photomultiplier tubes have evacuated glass envelopes. Allowing the glass to be scratched or to be subjected to shock can cause cracks. Especially, for tubes with graded sealing of synthetic silica, extreme care should be taken in handling.

● Helium permeation through silica bulb
Helium will permeate through the silica, leading to noise increase. Avoid operating or storing tubes in an environment where helium is present.

● Handling for tube with glass base
Glass base (also called button stem) is more fragile than plastic base. So care should be taken in handling this type of tube. For example, when making up the voltage divider circuit, solder divider resistors to socket lugs while the tube is inserted in the socket. Also, when cooling the tube at −50°C or below, although tubes are guaranteed for operation down to −80°C, use of contact pins instead of the normal socket is recommended. This is to prevent the stem from cracking from the difference in thermal expansion coefficient between the stem and socket.

● Keep faceplate and base clean
Do not touch the faceplate and base with bare hands. Dirt and fingerprints on the faceplate cause loss of transmittance and dirt on the base may cause ohmic leakage. Should it become soiled, wipe it clean using alcohol.

● Do not expose to strong light
Direct sunlight and other strong illumination should not be allowed to strike the photocathode, even when the tube is not operated.

The data and specifications are subject to change due to product improvement and other factors. Before specifying any of the types in your production equipment, please contact Hamamatsu.

Warranty

All Hamamatsu photomultipler tubes and related products are warranted to the original purchaser for a period of 12 months following the date of shipment. The warranty is limited to repair or replacement of any defective material due to defects in workmanship or materials used in manufacture.

A: Any claim for damage of shipment must be made directly to the delivering carrier within five days.

B: Customers must inspect and test all detectors within 30 days after shipment. Failure to accomplish said incoming inspection shall limit all claims to 75% of invoice value.

C: No credit will be issued for broken detectors unless in the opinion of Hamamatsu the damage is due to a bulb crack or a crack in a graded seal traceable to a manufacturing defect.

D: No credit will be issued for any detector which in the judgement of Hamamatsu has been damaged, abused, modified or whose serial number or type number have been obliterated or defaced.

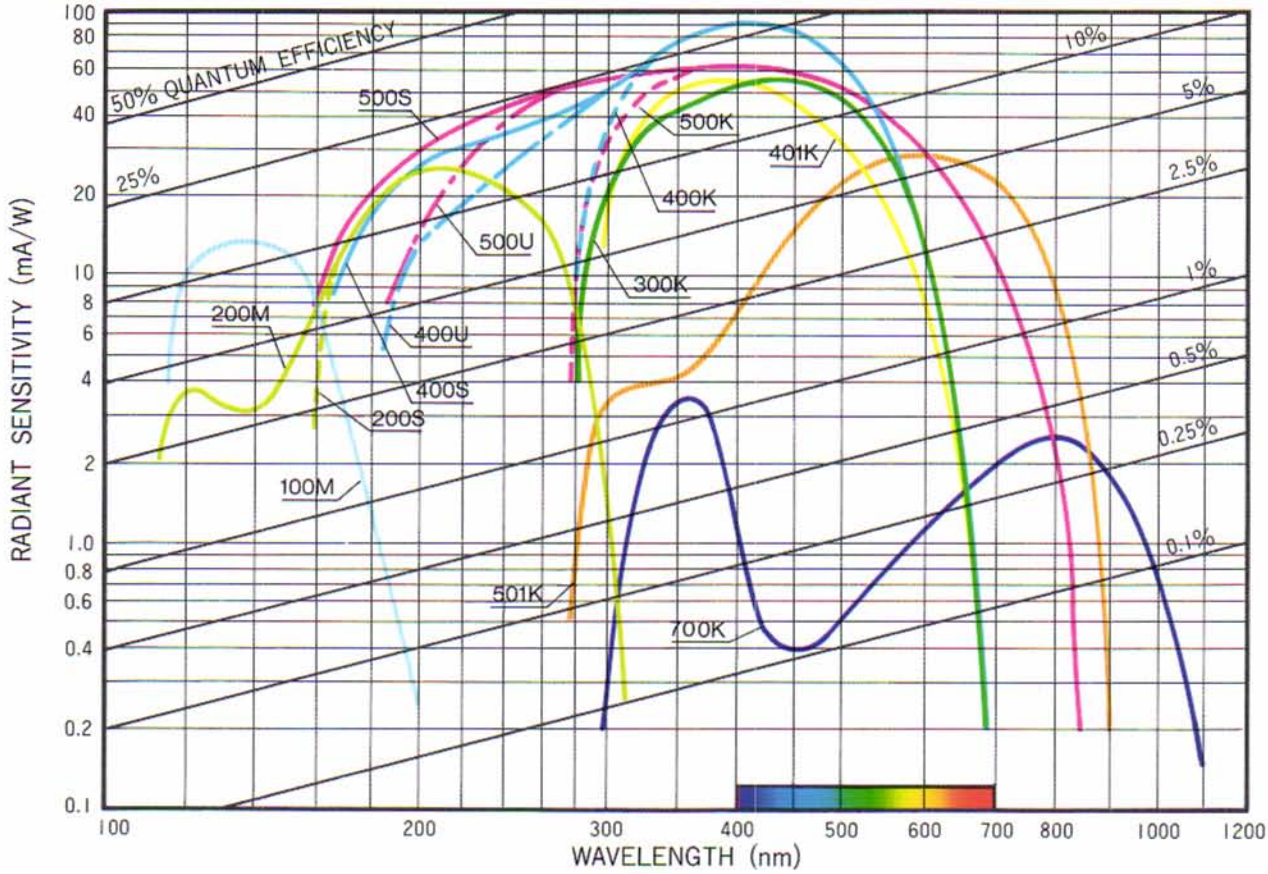
E: No detectors will be accepted for return unless permission has been obtained from Hamamatsu in writing, the shipment has been returned prepaid and insured, the detectors are packed in their original box and accompanied by the original datasheet furnished to the customer with the tube, and a full written explanation of the reason for rejection of each detector.

Typical Photocathode Spectral Response

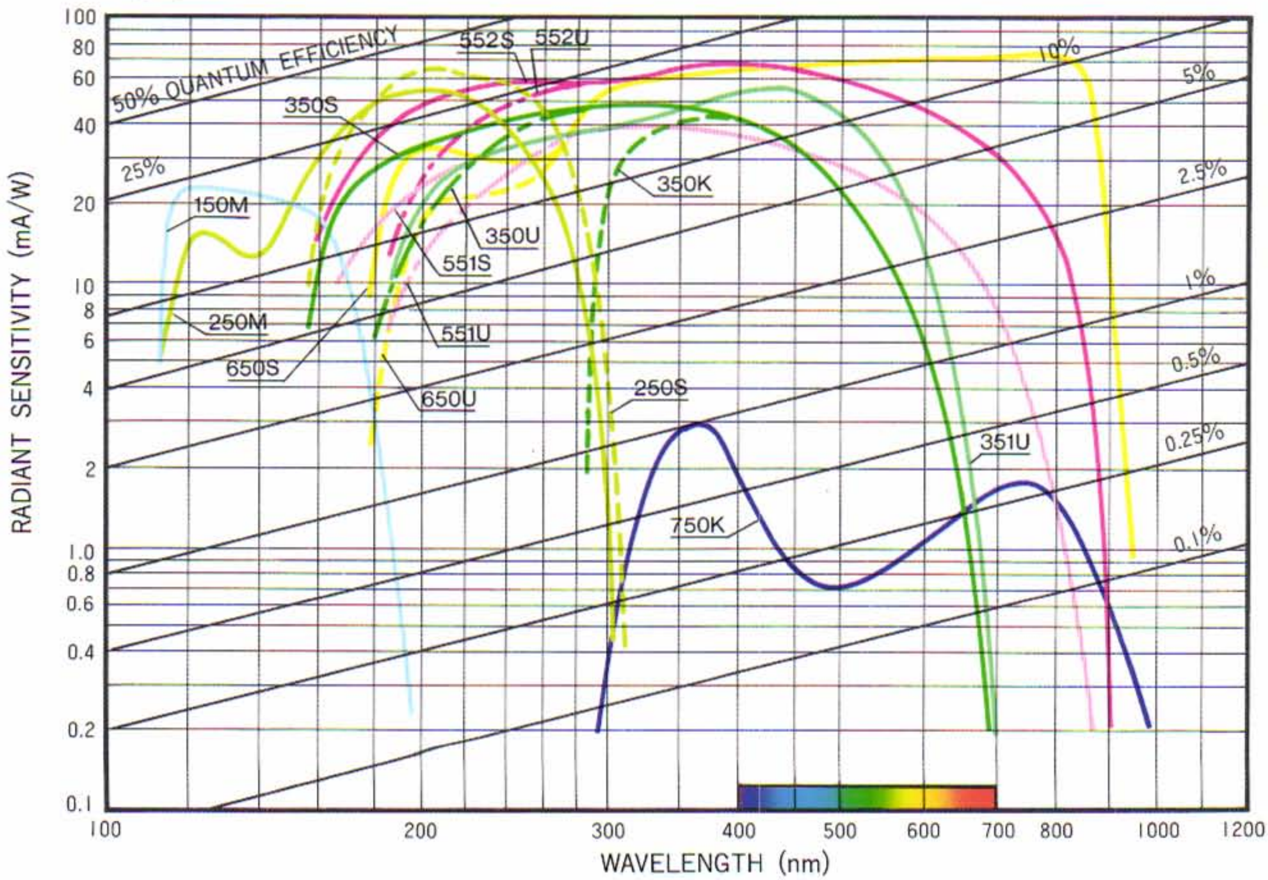
	Curve Codes	Photocathode Materials	Window Materials	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength of Radiant Sensitivity (nm)	Spectral Response: Peak Wavelength of Q.E. (nm)	PMT Examples
Semitransparent Photocathode (Transmission Mode)							
○	100M	Cs-I	MgF_2	115 ~ 200	140	130	R1081, R972, R1459, R2050
○	200S	Cs-Te	Synthetic silica	160 ~ 320	210	200	R1893, R759, R821, R431S
○	200M	Cs-Te	MgF_2	115 ~ 320	210	200	R1080, R1460
	201S	Cs-Te	Synthetic silica	160 ~ 320	240	220	R2078
	201A	Cs-Te	Sapphire	150 ~ 320	250	220	R1689-01
○	300K (S-11)	Sb-Cs	Borosilicate	300 ~ 650	440	410	6199, 7696
○	400K	Bialkali	Borosilicate	300 ~ 650	420	390	R647, R1213, R268, R580, R329, R878, R1306, R1213, R1250, R1635, R3082, etc.
○	400U	Bialkali	UV glass	185 ~ 650	420	390	R750, R269
○	400S	Bialkali	Synthetic silica	160 ~ 650	420	390	R760, R292, R331, R585, R2059, R2496, R3172, etc.
○	401K	High temp. bialkali	Borosilicate	300 ~ 650	375	360	R1281, R1288, R1282, R1044, R1640, R1317-05, R1519-01, R1705
	402K	Bialkali	Borosilicate	300 ~ 650	375	360	R1645U, R1564U, R2286U, R2287U, R2024U, R2809U, etc.
○	403U	Low noise bialkali	UV glass	185 ~ 680	375	320	R2693
○	500K (S-20)	Multialkali	Borosilicate	300 ~ 850	420	360	R1894, R1617, R1387, R550, R1513, R1925, PM55, R649
○	500U	Multialkali	UV glass	185 ~ 850	420	290	R1463, R1464, R374, R1508, R453, R567, R1104, R2027
○	500S	Multialkali	Synthetic silica	160 ~ 850	420	280	R376, R375, R562, R2368
○	501K	Multialkali	Borosilicate	300 ~ 900	650	600	R1333, R669, R1017, R649, R2066, R2228
○	700K (S-1)	Ag-O-Cs	Borosilicate	400 ~ 1200	800	780	R632, R316, R568, 7102, R1767
Opaque Photocathode (Reflection Mode)							
○	150M	Cs-I	MgF_2	115 ~ 195	120	120	R1259
○	250S	Cs-Te	Synthetic silica	160 ~ 320	200	200	R1657, R427, R166, R166UH
○	250M	Cs-Te	MgF_2	115 ~ 320	200	190	R1220
○	350K (S-4)	Sb-Cs	Borosilicate	300 ~ 650	400	350	R906, 931A, 1P21, R105, R105UH
○	350U (S-5)	Sb-Cs	UV glass	185 ~ 650	340	270	R1414, R300, R212, 1P28, R444, R212UH
○	350S (S-19)	Sb-Cs	Synthetic silica	160 ~ 650	340	210	R306, R106, R106UH
○	351U (Ext'd S-5)	Sb-Cs	UV glass	185 ~ 700	450	235	1P28A
	451U	Bialkali	UV glass	185 ~ 730	340	320	R372
	452U	Bialkali	UV glass	185 ~ 750	350	315	R905
	453K	Bialkali	Borosilicate	300 ~ 650	400	360	931B
	453U	Bialkali	UV glass	185 ~ 650	400	330	R1516
	454K	Bialkali	Borosilicate	300 ~ 680	450	430	R1785
	455U	Bialkali	UV glass	185 ~ 680	420	400	R1784
	456U	Low noise bialkali	UV glass	185 ~ 680	375	320	R1527, R2371, R2371-02
	457U	Bialkali	UV glass	300 ~ 680	450	450	R2752
	550U	Multialkali	UV glass	185 ~ 850	530	250	R1546, R1547, R500, R889
	550S	Multialkali	Synthetic silica	160 ~ 850	530	250	R1503
○	551U	Multialkali	UV glass	185 ~ 870	330	280	R446
○	551S	Multialkali	Synthetic silica	160 ~ 870	330	280	R456
○	552U	Multialkali	UV glass	185 ~ 900	400	260	R928
○	552S	Multialkali	Synthetic silica	160 ~ 900	400	215	R955
	554U	Multialkali	UV glass	185 ~ 900	450	370	R1477
	555U	Multialkali	UV glass	185 ~ 850	400	320	R777
	556U	Multialkali	UV glass	185 ~ 930	420	320	R936
	557U	Multialkali	UV glass	185 ~ 900	420	400	R1913
	558K	Multialkali	Borosilicate	300 ~ 800	530	510	R1923
	559U	Multialkali	UV glass	185 ~ 810	330	280	R508
○	650U	GaAs(Cs)	UV glass	185 ~ 930	300 ~ 700	300	R636
○	650S	GaAs(Cs)	Synthetic silica	160 ~ 930	300 ~ 700	280	R943-02
	651U	GaAs(Cs)	UV glass	185 ~ 910	350	270	R666, R666S
○	750K	Ag-O-Cs	Borosilicate	400 ~ 1100	730	730	R406
	850U	InGaAs (Cs)	UV glass	185 ~ 1010	400	330	R2658

○ : Spectral response curves are shown on page 77.

Semitransparent Photocathode



Opaque Photocathode



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Hamamatsu also supplies:
Solid State Detectors
Solid State Light Sources
Measuring Video Systems

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