

Selection Guide by Applications

Applications	Required Major Characteristics	Applicable PMT
Spectroscopy		
●Equipment Utilizing Absorption		
<p>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 can be used to yield analytical data. In order to determine the quantity of a sample substance, it is irradiated while its light wavelength is scanned continuously. The spectral intensities of the light before and after passing through the sample are then detected by a photomultiplier tube and the amount of absorption in this way measured.</p>	<ol style="list-style-type: none"> 1) Wide spectral response 2) High stability 3) Low dark noise 4) High quantum efficiency 5) Low hysteresis 6) Good polarization characteristics 	<p>R928, R955, R3896 R7639 R374</p>
<p>Atomic Absorption Spectrophotometer This is widely used in analysis of minute quantities of metallic elements. A special elementary hollow cathode lamp for each element to be analyzed is used to irradiate a sample which is burned to atomize it. A photomultiplier tube then detects the light passing through the sample to measure the amount of absorption, which is compared with a pre-measured reference sample.</p>		<p>R928 R955 R7154</p>
●Equipment Utilizing Emission		
<p>Photoelectric Emission Spectrophotometer When external energy is applied to a sample, that sample then emits light. By using a monochromator to disperse this light emission into characteristic spectral lines of elements and measuring their presence and intensity simultaneously with photomultiplier tubes, the photoelectric emission spectrophotometer can perform rapid qualitative and quantitative analysis of the elements contained in the sample.</p>	<ol style="list-style-type: none"> 1) High sensitivity 2) Low dark noise 3) High stability 	<p>R6350, R6351, R6352, R6354 R6355, R6356, R7311 1P28, R212, R1527 R7446, R8487</p>
<p>Fluorescence Spectrophotometer The fluorescence spectrophotometer is used in biological science, especially 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 known as fluorescence. The intensity and spectral characteristics of the fluorescence are measured by a photomultiplier tube, and the substance then analyzed qualitatively and quantitatively.</p>		<p>R6353, R6357, R6358 R3788, R4220, R1527 R928, R3896</p>
<p>Raman Spectroscopy When monochromatic light strikes a substance and scatters, a process called Raman scattering also occurs at a wavelength different from the excitation light. Since this wavelength differential is a unique characteristic of a molecule, spectral measurement of Raman scattering can provide qualitative and quantitative data of molecules. Raman scattering is extremely weak and a sophisticated optical system is required for measurement, with the photomultiplier tube operated in the photon counting mode.</p>	<ol style="list-style-type: none"> 1) High quantum efficiency 2) Less dark count 3) Single photon discrimination ability 	<p>R2949 R1463P, R649 R943-02 R9110</p>
<p>Other Spectrophotometric Equipment Using Photomultiplier Tubes</p> <ul style="list-style-type: none"> • Liquid or gas chromatography • X-ray diffractometers, X-ray fluorescence analyzers • Electron microscopes 		<p>R3788, R4220 R647-01, R1166, R6095, R580 R647 R7400U-01, R5900U-01</p>

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Mass Spectroscopy and Solid Surface Analysis

<p>Solid Surface Analysis</p> <p>The composition and structure of a solid surface can be studied by irradiating a narrow beam of electrons, ions, light or X-rays onto the surface and measuring the secondary electrons, ions or X-rays that are produced. Due to the rapid progress being made in the semiconductor industry, this kind of technology is essential for measuring semiconductors, including defects, surface analysis, adhesion, and density profile. Electrons, ions, and X-rays are measured with electron multipliers and MCPs.</p>	<ol style="list-style-type: none"> 1) High environmental resistance 2) High stability 3) High gain 4) Low dark current 	<p>R474, R515, R596, R595 R2362, R5150-10</p> <p>The above product is an electron multiplier</p>
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Pollution Monitoring

<p>Dust Counter</p> <p>A dust counter measures the density of dust or particles floating in the atmosphere or inside rooms. The dust counter makes use of light scattering or absorption of beta-rays by the dust particles.</p>	<ol style="list-style-type: none"> 1) Less dark count 2) Less spike noise 3) High quantum efficiency 	<p>R6350 R105, R3788 R647, R1924A, R6095</p>
<p>Turbidimeter</p> <p>When floating particles are contained in a liquid, the light incident on the liquid is absorbed, scattered or refracted by these particles. This process merely appears cloudy or hazy to the human eye. A turbidimeter is a device that numerically measures the turbidity by using light transmission and scattering.</p>	<ol style="list-style-type: none"> 1) Low dark current 2) Less spike noise 3) High quantum efficiency 	<p>R6350, R6357 R105, R7400U-01 R1924A</p>
<p>Other Pollution Monitoring Equipment Using Photomultiplier Tubes</p> <ul style="list-style-type: none"> • NOx meters, SOx meters 	<ol style="list-style-type: none"> 1) High quantum efficiency at target wavelengths 2) Low dark current 3) Good temperature characteristic 4) High stability 	<p>NOx= R3896, R5984, R374 R2228, R5929, R5070A H7844 SOx= R6095, R3788, R1527 R5983</p>

Biotechnology

<p>Flow Cytometer</p> <p>A flow cytometer uses a laser to irradiate cells labeled with fluorescent substance and measures the resulting fluorescence or scattered light from those cells with a photomultiplier tube, in order to identify each cell. A cell sorter is one kind of flow cytometer having the function of sorting specific cells.</p>		
<p>DNA Sequencer</p> <p>The DNA sequence is used to decode the base arrangement of DNA. When a voltage is applied across the both ends of a gelatinous substance (gel) into which DNA segments are injected, those DNA segments with a negative electric charge are drawn towards the plus electrode. The shorter the DNA segment, the faster it moves, resulting in a separation according to the DNA segment length. The base arrangement of each DNA segment can be determined by detecting the fluorescence emitted from the labeling pigment at the end of each DNA.</p>	<ol style="list-style-type: none"> 1) High quantum efficiency 2) High stability 3) Low dark current 4) High gain 	<p>R6357, R6358 R928, R3788 R4220, R3896 R7400U-01, R7400U-20 R5900U-01, R5900U-01-M4 R5900U-20, R5900U-20-M4 R5900U-20-L16 H7260-20 H7564B-20 H8711-20</p>
<p>DNA Microarray Scanner</p> <p>In this equipment, a DNA sample labeled by fluorescent dye is combined with a DNA probe having a large number of DNAs whose arrangement is known and fixed at a high density on a glass plate or silicon substrate. A laser beam is used to scan the sample and the resulting fluorescent intensity is measured to investigate the gene information.</p>		

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Medical Applications		
<p>Gamma Camera</p> <p>The gamma camera obtains an image of a radioisotope injected into the body of a patient to locate abnormalities. This equipment originated from a scintillation scanner and has been gradually improved. Its detection section uses a large diameter NaI(Tl) scintillator and light-guide coupled to a photomultiplier tube array.</p>	<ol style="list-style-type: none"> 1) High energy resolution 2) Good uniformity 3) High stability 4) Uniform gain (between each tube) 	<p>R6231-01, R6233-01 R6234-01, R6235-01 R6236-01, R6237-01 R1307-01 H8500C, H9500 R8900U-00-C12</p>
<p>Positron CT</p> <p>The positron CT provides tomographic images by detecting the coincident gamma-ray emission that accompanies the annihilation of positrons emitted from a tracer radioisotope (¹¹C, ¹⁵O, ¹³N, ¹⁸F, etc.) injected into the body. Photomultiplier tubes coupled to scintillators are used to detect these gamma-rays.</p>	<ol style="list-style-type: none"> 1) High energy resolution 2) High stability 3) Fast response time 4) Compact size 	<p>R1635, R8900U-00-C12 R1450 R7899 R1548-07 R6427 H8500C, H9500 R9420*, R9797*, R9800*</p>
<p>Liquid Scintillation Counter</p> <p>Liquid scintillation counters are used for tracer analysis in age measurement and biochemical research. A sample containing radioisotopes is dissolved into a solution containing an organic scintillator, and this is placed in the center between a pair of photomultiplier tubes. These tubes simultaneously detect the emission of the organic scintillator.</p>	<ol style="list-style-type: none"> 1) High quantum efficiency 2) Low thermionic emission noise 3) Less glass scintillation at bulb and other materials 4) Fast response time 5) High pulse linearity 	<p>R331, R331-05</p>
<p>In-Vitro Assay</p> <p>In-vitro assay is used for physical checkups, diagnosis, and evaluation of drug potency by making use of the specific antigen/antibody reaction characteristics of tiny amounts of insulin, hormones, drugs and viruses that are contained in blood or urine. Photomultiplier tubes are used to optically measure the amount of antigens labeled by radioisotopes or fluorescent, chemiluminescent or bioluminescent substances.</p> <ul style="list-style-type: none"> • Radioimmunoassay (RIA) Uses radioactive isotopes for labeling and scintillators for measurement. • Chemiluminoassay CLIA (Chemiluminoassay) CLEIA (Enzyme-intensified chemiluminoassay) Uses luminescent substances for labeling to measure chemiluminescence or bioluminescence. • Fluoroimmunoassay Uses fluorescent substances for labeling. 	<ol style="list-style-type: none"> 1) High quantum efficiency 2) High stability 3) Low dark current 	<p>R1166, R5610A, R5611A-01 R6350, R6352, R6353 R6356, R6357 R4220, R928, R3788, R3896 R647, R1463 R1925A, R1924A, R3550A R6095, R374 R7400U-01 R7400U-02 R7400U-20</p>
<p>Others</p> <ul style="list-style-type: none"> • X-ray phototimer This equipment automatically controls the X-ray film exposure during X-ray examinations. The X-rays transmitting through a subject are converted into visible light by a phosphor screen. A photomultiplier tube detects this light and converts it into electrical signals. When the accumulated electrical signal reaches a preset level, the X-ray irradiation is shut off, to allow obtaining an optimum film density. 	<ol style="list-style-type: none"> 1) High sensitivity 2) Low dark current 3) High stability 	<p>R6350 931A, R105</p>

* Individual data sheets are available.

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Radiation Measurement		
Area Monitor Area monitors are designed to continuously measure changes in environmental radiation levels. Area monitors use a photomultiplier tube coupled to a scintillator to monitor low level gamma-rays and beta-rays.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1306 R329-02 R1307 R877, R877-01
Survey Meter Survey meters are used to measure low level gamma-rays and beta-rays by using a photomultiplier tube coupled to a scintillator.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1635 R647 R1924A R6095 R7400U
Resource Inquiry		
Oil Well Logging Oil well logging is used to locate an oil deposit and determine its size. A probe containing a radiation source and a scintillator/photomultiplier tube is lowered into an oil well as it is being drilled. The scattered radiation or natural radiation from the geological formation is detected and analyzed, to determine the type and density of the rock that surrounds the well.	1) Stable operation at high temperatures up to 175 °C 2) Rugged structure resistant to shock and vibration 3) Good plateau characteristic	R4177-01 R3991A R1288A, R1288A-01 R9722 R4607-01
Industrial Measurement		
Thickness Meter The thickness meter uses a radiation source and a scintillator/photomultiplier tube detector to measure product thickness such as for paper, plastic, copper sheet on factory production lines. Beta-rays are used as a radiation source to measure small density products such as rubber, plastic, and paper. Gamma-rays are used for large density products such as copper plates. X-ray fluorescence is utilized to measure film thickness for plating, evaporation, etc.)	1) Wide dynamic range 2) High energy resolution	R647, R7899 R6095 R580 R1306, R6231 R329-02
Semiconductor Inspection System This is widely used for semiconductor wafer inspection and pattern recognition such as semiconductor mask alignment. In wafer inspection, the wafer is scanned by a laser beam, and the scattered light caused by dirt or defects is detected by a photomultiplier tube.	1) High quantum efficiency at target wavelengths 2) Good uniformity 2) Low spike noise	R3896 R7400U-01 R7400U-04 R7400U-20

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High Energy Physics		
●Accelerator Experiment		
Hodoscope Photomultiplier tubes are coupled to the ends of long, thin plastic scintillator arrays arranged in two layers intersecting with each other in order to measure the time and position at which charged particles pass through the scintillator arrays.	1) Fast response time 2) Compact size	R7400U Series, R7600U Series R1635 (H3164-10) R647-01 (H3165-10) R1450 (H6524), R1166 (H6520)
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 the time difference between the two counters.		3) Resistance to magnetic fields (when used in magnetic fields)
Cherenkov Counter A Cherenkov counter is used to identify secondary particles generated by the collision reaction of particles. Cherenkov radiation is emitted from charged particles with energy higher than a certain level when they pass through a gas or silicon aerogel. This weak Cherenkov radiation is detected by a photomultiplier tube. These particles are then identified by measuring the Cherenkov radiation emission angle.	1) High quantum efficiency 2) Single photon discrimination ability 3) High gain 4) Fast response time	R329-02 (H6410), R5113-02 R1250 (H6527), R1584 (H6528) R7600U Series
	5) Resistance to magnetic fields (when used in magnetic fields)	R5505-70 (H6152-70) R7761-70 (H8409-70) R5924-70 (H6614-70)
Calorimeter The calorimeter measures the accurate energy of secondary particles generated by the collision reaction of particles.	1) Good pulse linearity 2) High energy resolution 3) High stability	R580 (H3178-51) R7600U Series R329-02 (H6410)
	4) Resistance to magnetic fields	R5924 (H6614-70) R6091 (H6559)
●Neutrino and Proton Decay Experiment, Cosmic Ray Detection		
Neutrino Experiment Research on solar neutrinos or particle astrophysics is utilized in a neutrino experiment. This experimental system consists of a large amount of a medium surrounded by a great number of large-diameter photomultiplier tubes. When cosmic rays such as neutrinos enter and pass through the medium, their energy and traveling direction are measured by detecting Cherenkov radiation that occurs from interaction with the medium.	1) Large photocathode area 2) Fast time response 3) High stability 4) Less dark count	R5912* R7081* R8055* R3600-02*
Neutrino and Proton Decay Experiment In the neutrino and proton decay experiments being conducted at Kamioka, Japan, 11,200 photomultiplier tubes each 20" diameter are installed to surround from all directions a huge tank storing 50,000 t of pure water. The photomultiplier tubes are used to watch the subtle flash of Cherenkov radiation that occurs when proton decays or solar neutrinos pass through the pure water tank.		
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 gamma-rays and Cherenkov radiation emitted in this air shower are detected by photomultiplier tubes arranged in a lattice array on the ground.		R1166 (H6520) R580 (H3178-51) R329-02 (H6410) R6091 (H6559) R1250 (H6527) R6234

* These are listed in our catalog "Photomultiplier Tubes and Assemblies for Scintillation Counting & High Energy Physics".

The assembly type is given in parentheses.

Applications	Required Major Characteristics	Applicable PMT
Aerospace		
Astronomical X-ray Measurement X-rays from outer space include information on the enigmas of space. As an example, the X-ray observation satellite "Asuka" developed by a group of the ISAS (Institute of Space and Astronomical Science - Japan), uses a gas-scintillation proportional counter in conjunction with a position-sensitive photomultiplier tube to measure X-rays from supernovas, etc.	<ol style="list-style-type: none"> 1) High energy resolution 2) Resistance to shock and vibration 	R3998-02 R3991A R6231 R2486 Ruggedized PMT with high resistance to vibration and shock will be required. Consult with our sales office.
Measurement of Scattered Light from Fixed Stars and Interstellar Dust Ultraviolet rays from space contain a great deal of information about the surface temperatures of stars and interstellar substances. However, these ultraviolet rays are absorbed by the earth's atmosphere making it impossible to measure them from the earth's surface. So photomultiplier tubes are mounted in rockets or artificial satellites, to measure ultraviolet rays with wavelengths shorter than 300 nm.	<ol style="list-style-type: none"> 1) Resistance to shock and vibration 2) Sensitivity only in VUV to UV range (Solar blind response with no sensitivity to visible light: See page 6 for Cs-Te and CsI photocathodes) 	R1080, R976 R6834, R6835, R6836 Ruggedized PMT with high resistance to vibration and shock will be required. Consult with our sales office.
Lasers		
Laser Radar The laser radar is used in applications such as atmospheric measurement for highly accurate range finding or aerosol scattering detection.	<ol style="list-style-type: none"> 1) Fast time response 2) Less dark count 3) High gain 4) Less afterpulses 	R3809U Series R5916U Series R3234-01 R7400U-20, R3896
Fluorescence Lifetime Measurement A laser is used as an excitation light for fluorescence lifetime measurement. The molecular structure of a substance can be studied by measuring the changes in temporal intensity in the emitted fluorescence.		R3809U Series R5916U Series R5900U-01, R5900U-01-M4 R5900U-20, R5900U-20-M4 H7546B-01, H7546B-20 H8711-01, H8711-20
Plasma		
Plasma Observation Photomultiplier tubes are 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 on plasma using Thompson scattering and the Doppler effect to observe the spatial distribution of plasma, and to measure impurities in the plasma with the objective of controlling impurities and ions.	<ol style="list-style-type: none"> 1) High detection capability at low light level 2) Quantum efficiency with less wavelength dependence 3) Gate operation 	R2257 R1104 R943-02