TECHNICAL INFORMATION May 1999

RUGGEDIZED HIGH TEMPERATURE PHOTOMULTIPLIER TUBES

HAMAMATSU

Contents

1. Photomultiplier Tubes

1-1 Plateau change with the LLD

Graphs in Figures 1 (a) to (c) show the plateau center voltage, plateau start voltage and plateau length characteristics for the R1288 and R3991 photomultiplier tubes. Each graph was plotted while changing the LLD (low level discrimination) from 0.8pC to 1.5pC and to 2.8pC with a sampling window of ±5% specified during plateau measurements using a ^{137}Cs radiation source and an NaI(Tl) scintillator. As (a) and (b) of these figures show, the plateau voltage lowers as the LLD is set to smaller points, because signal pulses with low pulse height are also counted so that the signals appear at low supply voltages. In contrast, when the LLD is set to larger points, the plateau voltage shifts to the higher voltage side. If the LLD is set too high, the plateau voltage may exceed the maximum rating. So it is important that the LLD be adjusted to obtain a plateau voltage within the rated voltage.

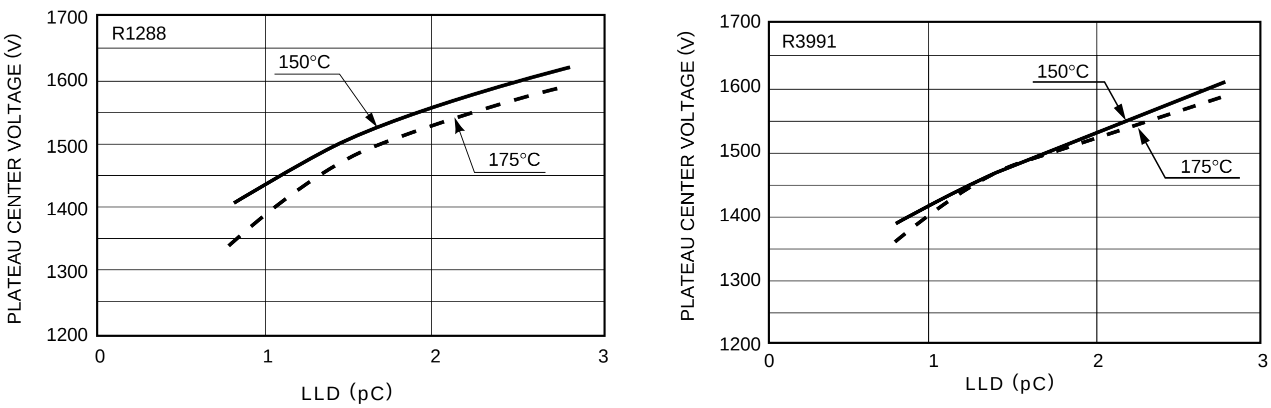

Figure 1 (a): Plateau center voltage vs. LLD for R1288 (left) and R3991 (right)

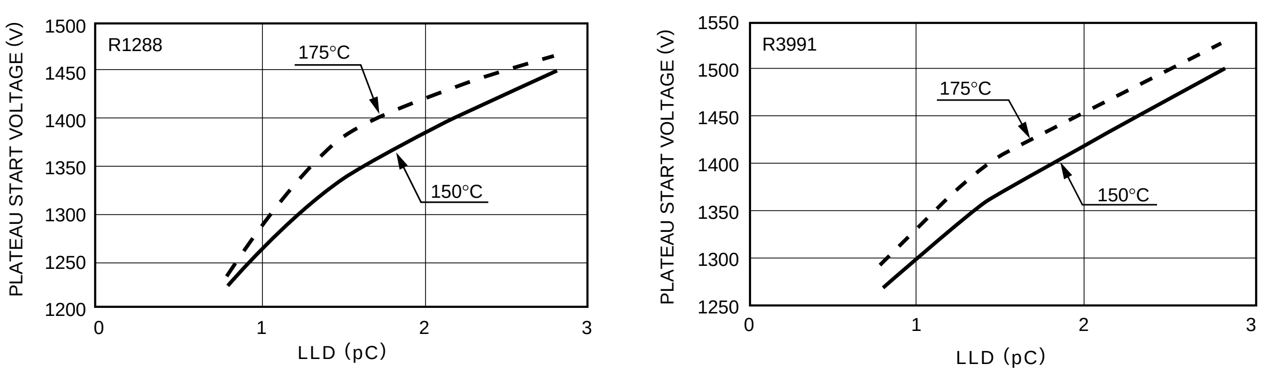

Figure 1 (b): Plateau start voltage vs. LLD for R1288 (left) and R3991 (right)

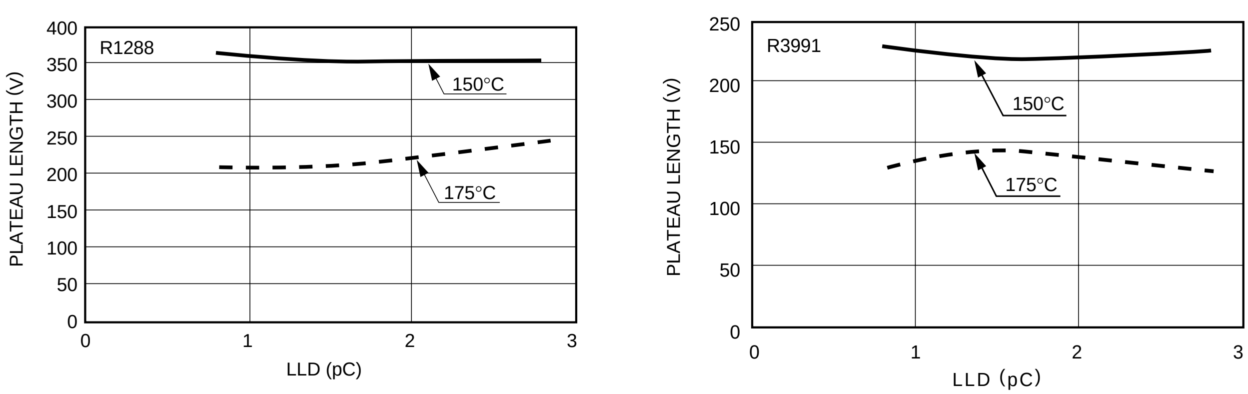

Figure 1 (c): Plateau length vs. LLD for R1288 (left) and R3991 (right)

1-2 Plateau measurement using a blue LED

Plateau measurement is usually performed with a combination of a ^{137}Cs radiation source and an NaI(Tl) scintillator, which serves as the light source. However, pulsed light from a blue LED can also be used to measure plateau characteristics. Advantages of using a blue LED are that differences in the emission efficiency of NaI(Tl) scintillators and variations over time can be eliminated. In addition, the LED is set outside the temperature-controlled chamber so it is not exposed to high temperatures during measurement. This means that inherent characteristics of photomultiplier tubes can be measured.

Furthermore, plateau measurement using scintillators often requires a large number of scintillators and also extra processes for measurement setups. This results in more work and increased cost in order to supply customers with plateau measurement data. Using blue LEDs allows simultaneous measurement of many photomultiplier tubes and supplying data with a minimum cost increase.

Figures 2 and 3 show comparisons of plateau length data measured using scintillators and blue LEDs. As can be seen, this data shows a good correlation. The block diagram of the test using a blue LED is also shown in Figure 4.

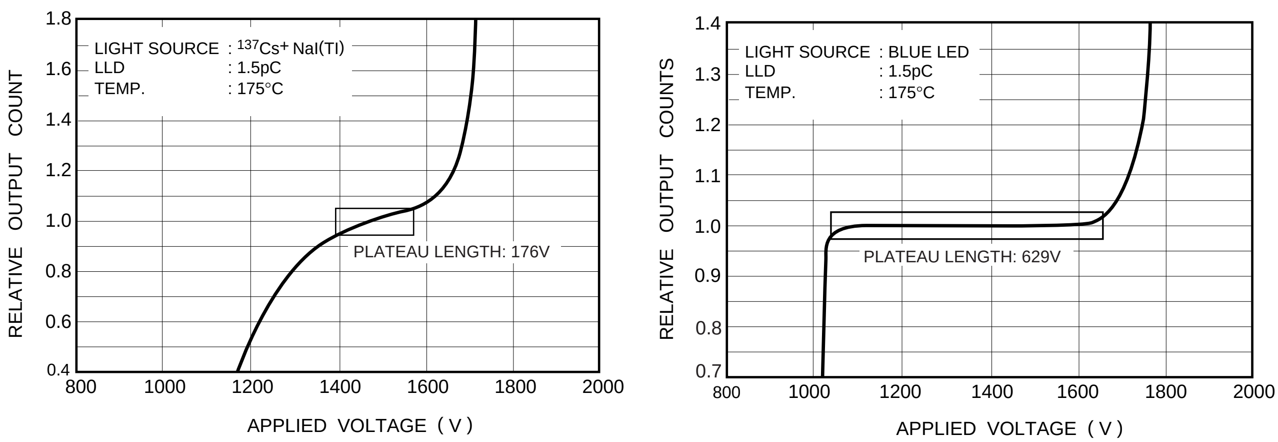

Figure 2: Plateau characteristics of R3991 measured with scintillator (left) and blue LED (right)

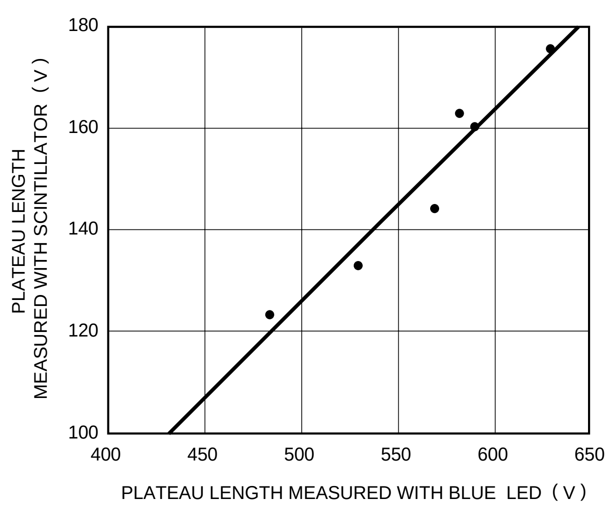

Figure 3: Correlation of plateau length data measured with scintillator and blue LED

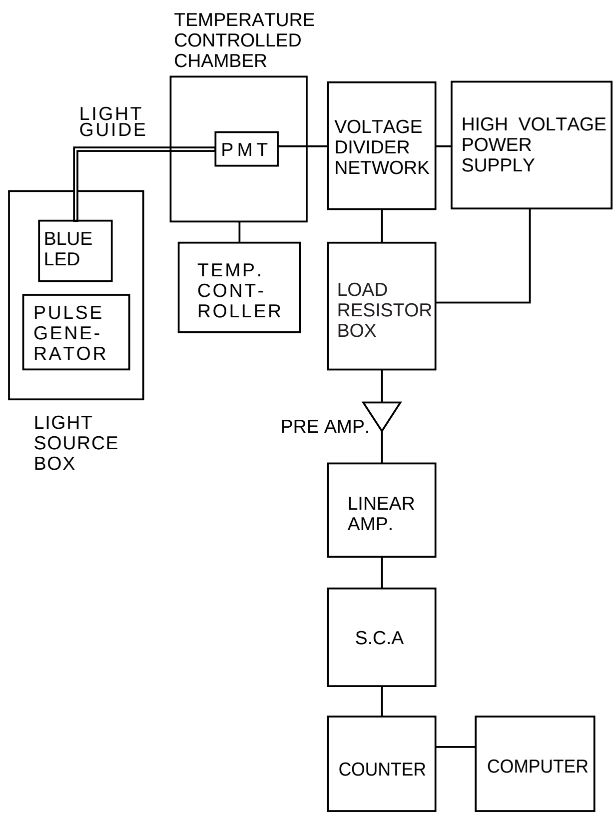

Figure 4: Plateau test block diagram

1-3 Life characteristics under high temperatures

Figure 5 shows output data for R1288 and R3991 photomultiplier tubes obtained by high temperature operation tests at 175°C and 150°C. These photomultiplier tubes are manufactured by means of a special activation process to fabricate a photocathode that withstands high temperatures. Due to this special process, the service life characteristics under high temperatures vary from type to type, or even tube to tube. Although Figure 5 shows typical data, the R3991 exhibits a slightly larger deterioration under high temperatures than the R1288.

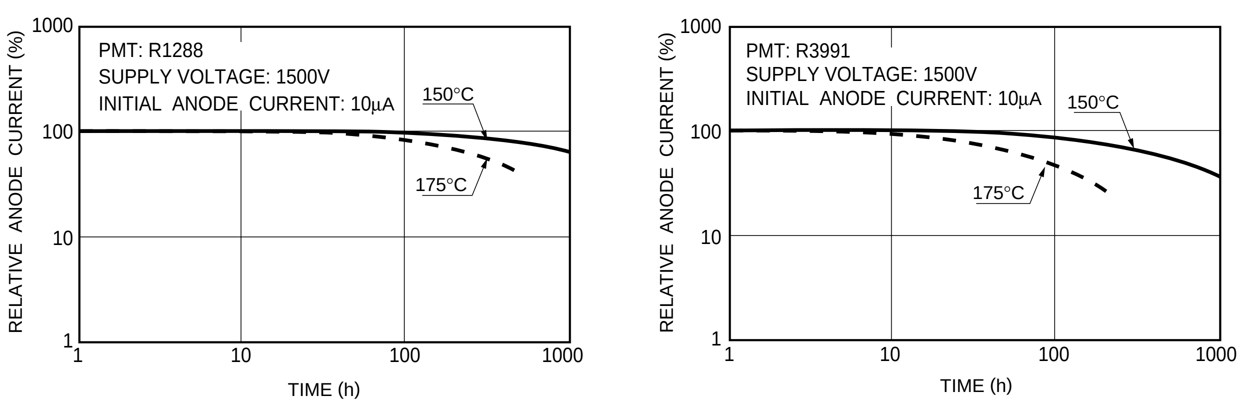

Figure 5: High temperature operation test data for R1288 (left) and R3991 (right)

1-4 Characteristics changes by applying vibrations

Figures 6 and 7 show how characteristics of ruggedized photomultiplier tubes vary when sinusoidal vibrations of 30G and random vibrations of 20Grms are applied. Each tube was vibrated for 30 minutes along each of three orthogonal axes as one cycle of the vibration test, so the total time for applying the vibrations was one hour and 30 minutes. Vibrations were applied three times during this test (3 sweeps per axis), but no significant problems were found. (If the photomultiplier tube is tested by only applying sinusoidal vibrations, then one test cycle is equivalent to the maximum rating of the photomultiplier tube.)

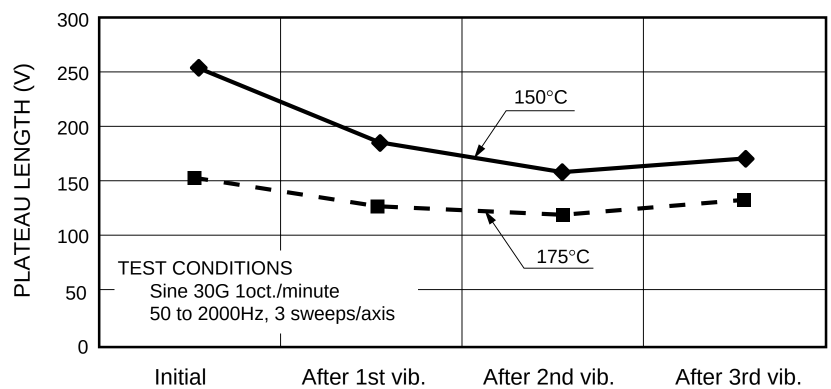

Figure 6: Sinusoidal vibration test data

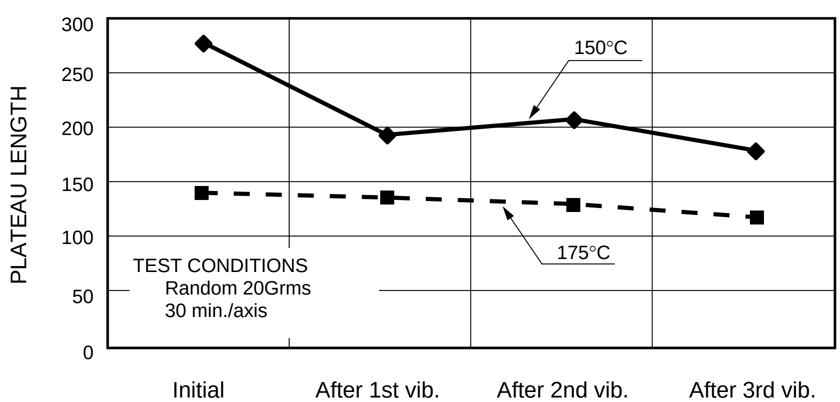

Figure 7: Random vibration test data

2. Photomultiplier Tube Assemblies

Photomultiplier tube assemblies listed in our catalog for high temperature applications have internal connections which allow operation with either a negative or positive high voltage input. The following explains precautions to be taken when using a photomultiplier tube assembly with a negative or positive high voltage input.

2-1 Using with positive high voltage input

Since a positive high voltage is applied to the anode in this circuit, a coupling capacitor is required for connecting to an external measuring unit. Figure 8 shows a typical connection. The right component must be selected to transmit the anode output waveform correctly.

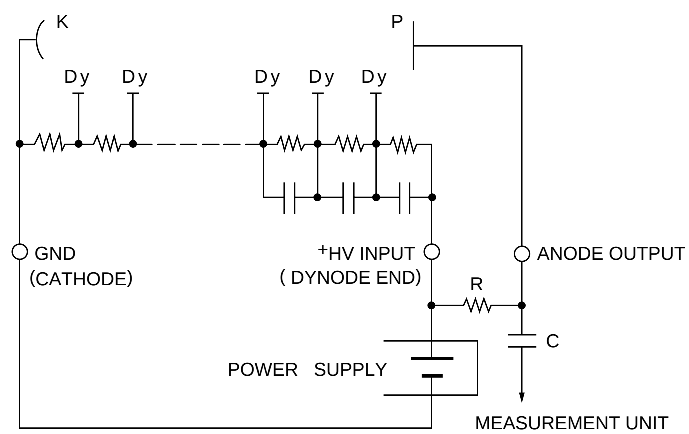

Figure 8: Anode high voltage connection (cathode ground)

When the output pulse width from the photomultiplier tube is sufficiently short compared to the time constant of the coupling capacitor circuit, the anode output is transmitted to the measuring unit without distortion regardless of the capacitor value. However, if the capacitor value does not match the output pulse width, the output will have a differential waveform. In contrast, when the time constant is larger than necessary, a base line shift, in which the ground level during measurement differs from the actual ground level, may occur depending on the count rate. When used with a ^{137}Cs radiation source and NaI(Tl) scintillator, we recommend selecting a capacitor between 1000pF and 0.01µF and a resistor between 100 kilohms to 1 megohms. In particular, it is important to select a capacitor which has small leakage current even at high temperatures.

Hamamatsu photomultiplier tube assemblies use high-quality capacitors manufactured by KD Components, Inc. or SIERRA Aerospace Technology, Inc. The voltage rating of these capacitors should be at least 1.5 times the maximum rating voltage of the photomultiplier tube. The rating for example should be at least 3kV for the R1288 and R3991, and at least 5kV for the R1317 and R5473.

When coupling capacitors are used under high temperatures, their rated capacitance usually varies and their electrical insulation also degrades causing leakage current and noise. It is therefore necessary to check and test the selected components under operating conditions equivalent to those in their actual environment.

Since the anode is applied at a high voltage in this positive high voltage operation, be sure to provide good insulation between the anode and external circuits and components. Preferably, install external components in locations as close to the photomultiplier tube as possible.

2-2 Using with negative high voltage input

The negative high voltage operation has an advantage in terms of component cost because the external CR circuit necessary for positive high voltage operation can be eliminated. However, the potential difference between the cathode at a high voltage and the peripheral parts may cause noise, so caution is required when installing the photomultiplier tube. The standard case of photomultiplier tube assemblies listed in our catalog is floating to allow for either positive or negative high voltage operation. So in actual operation, even if the case makes contact with the equipment housing at ground potential when installing the photomultiplier tube assembly, no problem will occur. However, poor contact with the equipment housing may cause the case potential to change between the floating state and ground level. This creates increased noise in the output signal. Photomultiplier tube assemblies with stainless steel cases must be clamped securely when the external housing is at ground potential, but drilling screw holes in the case should be avoided.

Photomultiplier tube assemblies with shield cases (magnetic shields) have painted surfaces which do not make good electrical contact with the other parts. Here, wrapping capton tape around the case surface to form insulation or other methods will prove effective in minimizing noise.

Another point which should be noted is that when the scintillator case at ground level is in direct contact with the photomultiplier tube faceplate, light emission may occur in the photomultiplier tube glass bulb due to the difference in potential between the cathode at a negative high voltage and the scintillator case, resulting in increased noise. Figure 9 shows dark pulses when the R1288-27 photomultiplier tube is operated at a high voltage of -1500V. Dark pulse behavior does not change even when the stainless case is connected to ground level. However, as shown in Figure 10, noise pulse height becomes greater when metal at ground potential makes contact with the photomultiplier tube faceplate. So taking the photomultiplier tube and scintillator dimensions as well as possible electrical contact into account is also very important.

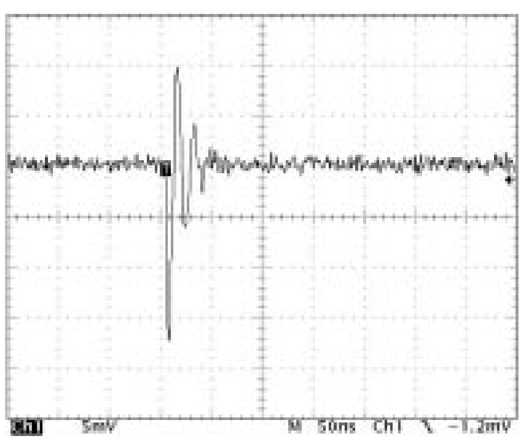

Figure 9: Dark pulses of R1288-27
(operated at -1500V)

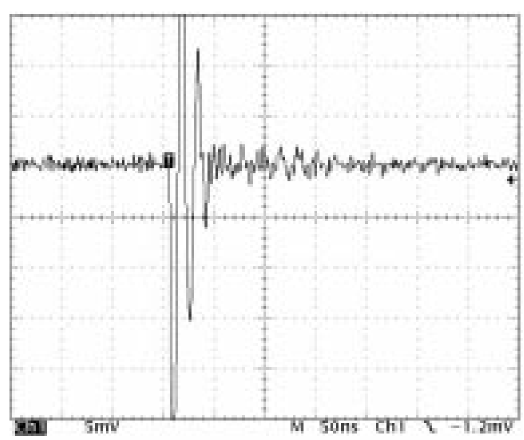

Figure 10: Dark pulse increase
(when ground potential metal makes contact with faceplate)

2-3 Soldering

The properties of the solder must be taken into account when soldering necessary components onto a printed circuit board or soldering cable connections.

1) Effect of soldering flux

Soldering flux is indispensable for making a good electrical connections with solder. However, at high temperatures, flux tends to ooze out from the solder joint. Some types of solder contain chlorine which may cause problems such as corrosion of the circuit board pattern or wiring breaks after long term use. Solder in Japan is classified according to the JIS (Japanese Industrial Standards). If available, use of soldering flux conforming to RMA standards (USA) is recommended.

2) Types and composition

There are many different types of solder, so the operating conditions must be considered when selecting the solder. High temperature ruggedized photomultiplier tubes are designed for a temperature standard of 175°C. However, using solder with an operating temperature (liquid-phase temperature) up to at least 220°C is recommended. Solder is mainly said to be comprised of tin (Sn), lead (Pb) and silver (Ag). The effects from impurities contained in the solder are listed below as a reference.

Impurities	Mechanical Properties	Solderability	Others
Sb	Adds tensile resistance Adds tensility	Less adhesion Weaker flow properties	Increases electrical resistance
Bi	Becomes brittle	–	Cracks when cooled
Zn	–	Weaker flow properties Weaker joint	Porous, surface become rough and granular
Al	Less adhesion	Weaker flow properties	Prone to oxidation and corrosion
As	Becomes brittle	–	Forms bubbles or needle-like crystals
P	–	–	Corrosion forms on copper
Cd	Becomes brittle	Weak luster	Porous, whitening
Cu	Becomes brittle	Weaker flow properties	
Ni	Becomes brittle	Less adhesion	

2-4 Changes in solder with age

The composition of solder changes over time even though its appearance seems the same. Figure 11(a) shows solder right after soldering, the black portions are oversaturated tin. The excess tin crystallizes inside the solder as time passes and a typical condition after 120 days is shown in Figure 11(b). The connective or joint strength of the solder changes as the structure of the solder gradually becomes rough. This change is further accelerated by high temperatures and expansion/contraction stresses. The changes are unavoidable and effect the nature of the solder itself. It is important to find by trial and error just what kind of solder works best on the actual circuit board and components to be used. Finding the optimal material in this way will improve reliability.

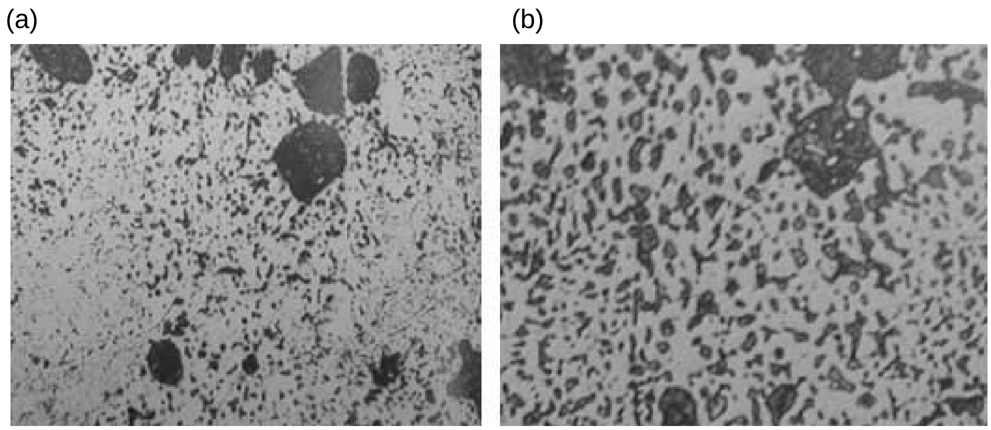

Figure 11: (a) Solder structure right after soldering; (b) Solder structure 120 days after soldering

2-5 Handling the cable

The photomultiplier tube potted in a case has in internal strain relief structure to withstand an external pulling force. However improper handling will shorten the product service life and cause malfunctions.

• Cable handling precautions for photomultiplier tube case

The point where the cable comes out of the photomultiplier tube case has silicone potting or an end cap. However in either case, pulling on the cable should still be avoided. If a load has to be applied, it should still be limited to within 5 kilograms. The cable should still be kept as straight as possible and bending it should be avoided especially on the end connecting to the photomultiplier tube case. (See Figure 12.)

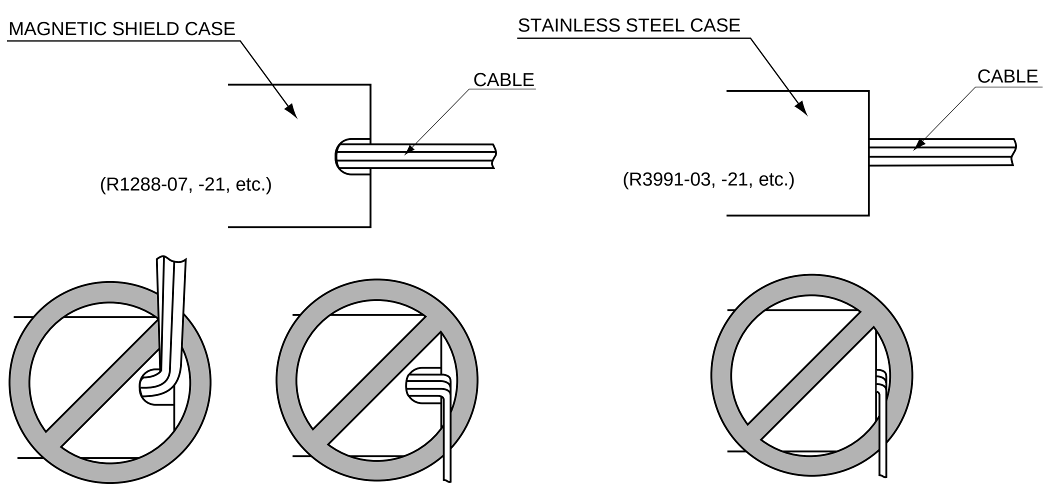

Figure 12: Cable handling precautions for photomultiplier tube case

Caution is needed when laying out cable wiring when vibrations are applied, especially for applications using high temperature photomultiplier tubes.

1) A cable of the correct length should be used. If the cable is too long, wear and conductor fatigue may occur due to vibration. The standard cable length for catalog products is 8 inches. In this case as a general guide, the sway width should be limited to half an inch. Wire breaks may occur if there is no excess to take up strain due to vibration. Take measures such as bundling and securing the wiring in place.

2) The bent parts of the cable must be kept away from each other when the cables are bundled together. Also do not randomly rout photomultiplier tube cables together with other types of cables. Placing them together may shorten the actual bend radius of the cable. When laying out cables together, cover them with a teflon tube shield and secure in place (clamp) from atop this shield as illustrated below.

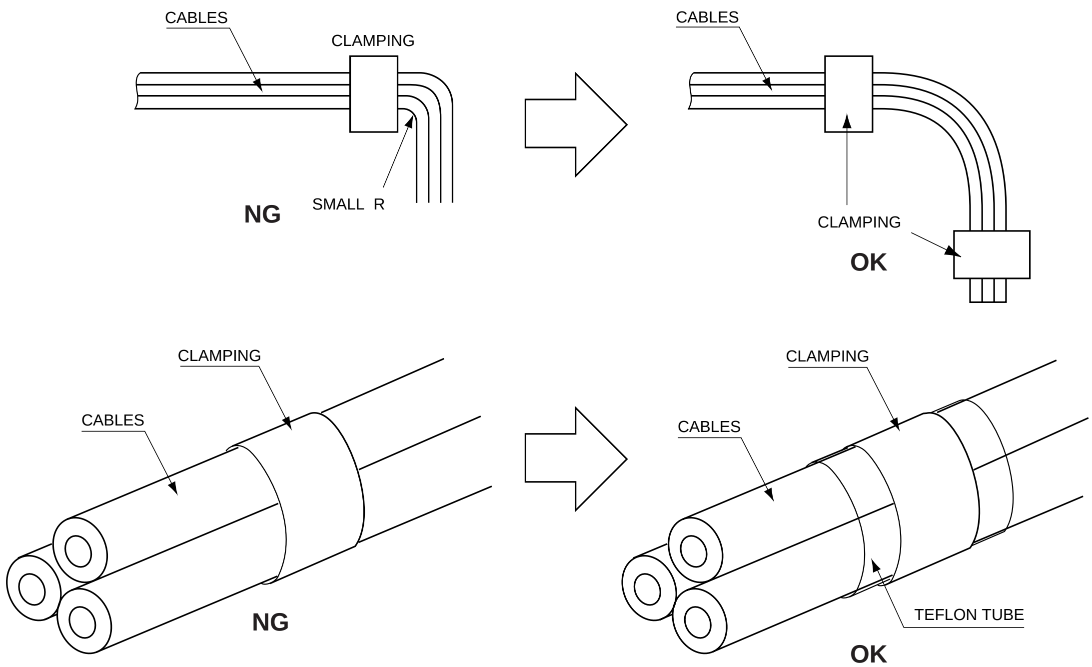

Figure 13: Clamping cables

2-6 Protecting the photomultiplier tube internal structure

A fixed pressure should be applied to maintain the sealing when the photomultiplier tube is used with a scintillator. However an incorrect installation may lead to damage or operating problems with the photomultiplier tube. (Figure 14 shows this example.) In particular, on products where the cable end has been potted, a pressure from the rear side is directly applied internally on the photomultiplier tube so any installation method that applies pressure directly on the potting surface must be avoided.

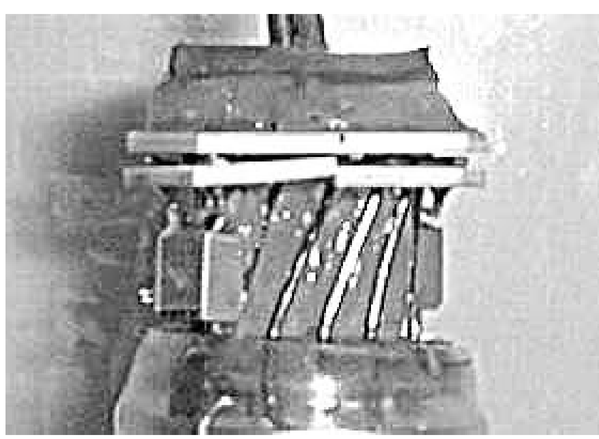

Figure 14: Warping of photomultiplier tube leads and circuit board damage due to pressure from the rear side

• Typical installation

To avoid possible problems, a design is needed in which the force from installing the housing is applied to the photomultiplier tube case rather than the potting. Even in this case, the force applied when coupling the scintillator must be adequately controlled. Maintaining this force within 20kg is recommended.

On the R1288 having a magnetic shield, the silicone potting surface is inner than the case edge. Therefore, do not apply force to the silicone potting but apply to the entire case. When force is applied to the silicon potting of the R3991, it should be within a range of 2mm from the case surface. (See Figure 15.)

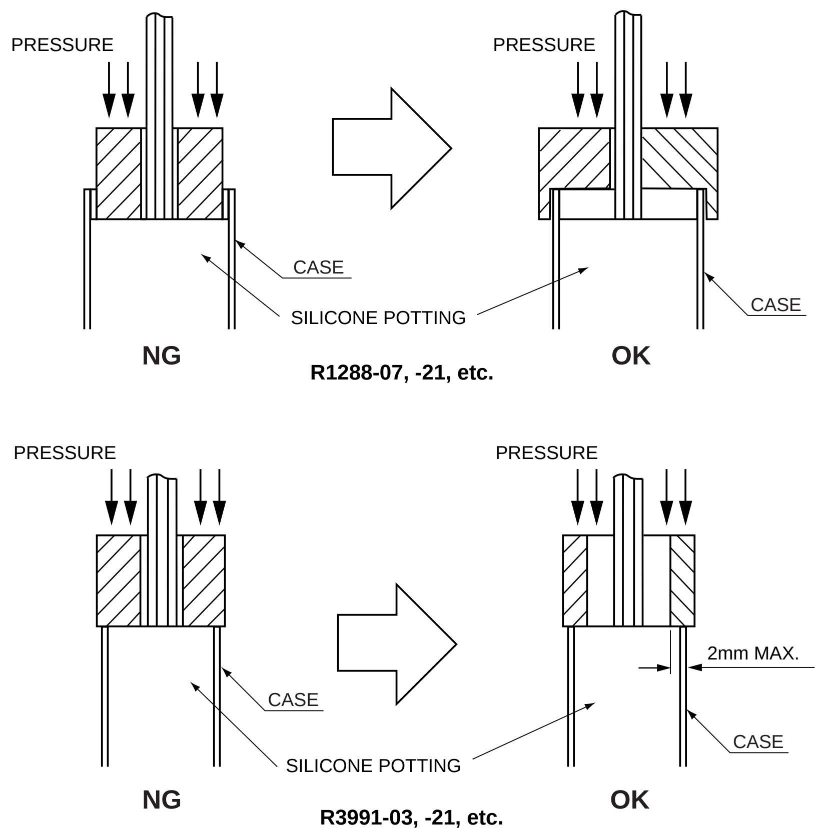

Figure 15: Applying force to photomultiplier tube case

Mechanical stress is another factor which cannot be ignored under high temperature environment. To avoid troubles which may be caused by thermal expansion stress if the photomultiplier tube assemblies are completely fixed mechanically, use springs or elastic materials when securing these assemblies. In this case however, provide space or clearance to relieve possible stress taking account of the spring constant or the thermal expansion of elastic materials.

2-7 Coupling to the scintillator

Soft, flexible material is used in certain internal sections of the photomultiplier tube case in order to protect the body of the photomultiplier tube from expansion forces due to high temperatures. This means that the device protecting the photomultiplier tube inside the case may break if excessive force is applied when coupling the scintillator onto the photomultiplier tube faceplate. This causes a condition called "slide back" in which the photomultiplier tube slides further back into the case where it cannot make a satisfactory coupling with the scintillator.

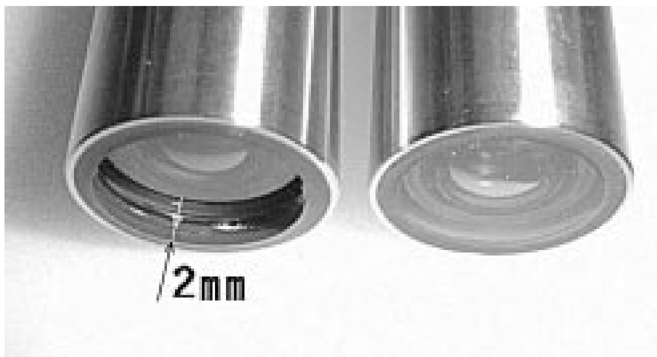

Figure 16: Photomultiplier tube "slideback" (shown at left)

The scintillator case should preferably be larger than the photomultiplier tube case in order to avoid this slide back problem. If the scintillator case is smaller than the photomultiplier tube, adding an adapter to the housing or taking some other measure is essential. A further item for attention is the faceplate of the photomultiplier tube which protrudes about 0.5mm from the case. In order to maintain a satisfactory coupling, it is advisable to install a 0.3 to 0.5mm teflon sheet or similar protective material around a stainless steel case which is somewhat larger than the photomultiplier tube. (See Figure 17.)

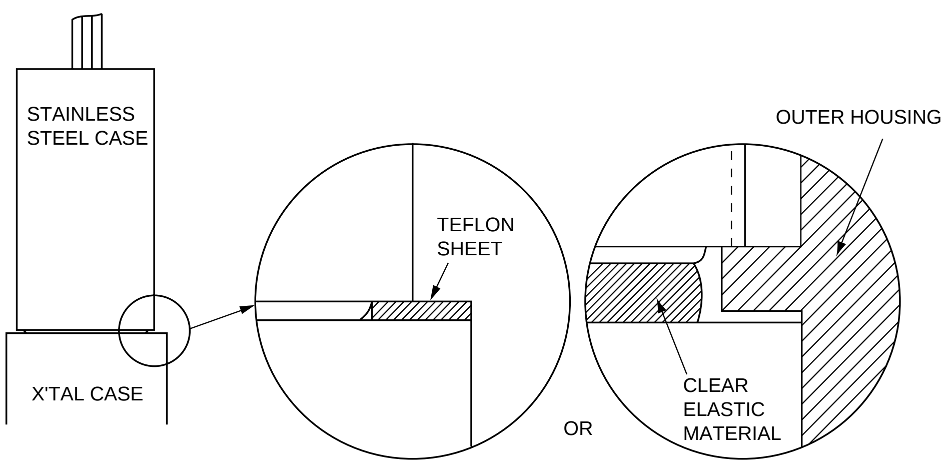

Figure 17: Coupling scintillator to photomultiplier tube faceplate

MEMO

HAMAMATSU

HAMAMATSU PHOTONICS K.K., Electron Tube Center
314-5, Shimokanzo, Toyooka-village, Iwata-gun, Shizuoka-ken, 438-0193, Japan
Telephone: (81)539/62-5248, Fax: (81)539/62-2205
http://www.hamamatsu.com

Main Products

Opto-semiconductors
Photodiodes
Photo ICs
Position Sensitive Detectors
Image Sensors
Infrared Detectors
Solid State Emitters
CdS Photoconductive Cells
Pyroelectric Detectors
Photocouplers
Photointerrupters, Photoreflectors

Electron Tubes
Photomultiplier Tubes
Light Sources
Microfocus X-ray Sources
Image Intensifiers
X-ray Image Intensifiers
Microchannel Plates
Fiber Optic Plates

Imaging and Processing Systems
Video Cameras for Measurement
Image Processing Systems
Streak Cameras
Optical Oscilloscopes
Optical Measurement Systems
Imaging and Analysis Systems

Sales Offices

ASIA:
HAMAMATSU PHOTONICS K.K.
325-6, Sunayama-cho,
Hamamatsu City, 430-8587, Japan
Telephone: (81)53-452-2141, Fax: (81)53-456-7889

U.S.A.:
HAMAMATSU CORPORATION
Main Office
360 Foothill Road, P.O. BOX 6910,
Bridgewater, N.J. 08807-0910, U.S.A.
Telephone: (1)908-231-0960, Fax: (1)908-231-1218
E-mail: usa@hamamatsu.com

Western U.S.A. Office:
Suite 110, 2875 Moorpark Avenue
San Jose, CA 95128, U.S.A.
Telephone: (1)408-261-2022, Fax: (1)408-261-2522

United Kingdom:
HAMAMATSU PHOTONICS UK LIMITED
Lough Point, 2 Gladbeck Way, Windmill Hill,
Enfield, Middlesex EN2 7JA, United Kingdom
Telephone: (44)181-367-3560, Fax: (44)181-367-6384

France, Portugal, Belgium, Switzerland, Spain:
HAMAMATSU PHOTONICS FRANCE S.A.R.L.
8, Rue du Saule Trapu, Parc du Moulin de Massy,
91882 Massy Cedex, France
Telephone: (33)1 69 53 71 00
Fax: (33)1 69 53 71 10

Swiss Office:
Richtersmattweg 6a
CH-3054 Schüpfen, Switzerland
Telephone: (41)31/879 13 13,
Fax: (41)31/879 18 74

Belgian Office:
7, Rue du Bosquet
B-1348 Louvain-La-Neuve, Belgium
Telephone: (32)10 45 63 34
Fax: (32)10 45 63 67

Spanish Office:
Centro de Empresas de Nuevas Tecnologies
Parque Tecnologico del Valles
08290 CERDANYOLA, (Barcelona) Spain
Telephone: (34)93 582 44 30
Fax: (34)93 582 44 31

Germany, Denmark, Netherland:
HAMAMATSU PHOTONICS DEUTSCHLAND GmbH
Arzbergerstr. 10,
D-82211 Herrsching am Ammersee, Germany
Telephone: (49)8152-375-0, Fax: (49)8152-2658

Danish Office:
Erantisvej 5, Tilst
DK-8381 Mundelstrup, Denmark
Telephone: (45)4346/6333, Fax: (45)4346/6350

Netherland Office:
Postbus 536, 3760 Am Soest, Netherland
Telephone: (31)35-6029191, Fax: (31)35-6029304

North Europe:
HAMAMATSU PHOTONICS NORDEN AB
Smidesvägen 12
SE-171 41 SOLNA, Sweden
Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01

Italy:
HAMAMATSU PHOTONICS ITALIA S.R.L.
Strada della Moia, 1/E
20020 Arese, (Milano), Italy
Telephone: (39)02-935 81 733
Fax: (39)02-935 81 741

Hong Kong:
S&T ENTERPRISES LTD.
Room 404, Block B,
Seaview Estate, Watson Road,
North Point, Hong Kong
Telephone: (852)25784921, Fax: (852)28073126

Taiwan:
S&T HITECH LTD.
3F-6, No. 188, Section 5, Nanking East Road
Taipei, Taiwan R.O.C
Telephone: (886)2-2753-0188
Fax: (886)2-2746-5282

KORYO ELECTRONICS CO., LTD.
9F-7, No.79, Hsin Tai Wu Road
Sec.1, Hsi-Chih, Taipei, Taiwan, R.O.C.
Telephone: (886)2-2698-1143, Fax: (886)2-2698-1147

Republic of Korea:
SANGKI TRADING CO., LTD.
Suite 431, Sunmyunghoi Bldg.,
24-2, Yoido-Dong, Youngdeungpo-ku,
Seoul, Republic of Korea
Telephone: (82)2-780-8515
Fax: (82)2-784-6062

Singapore:
S&T ENTERPRISES (SINGAPORE) PTE. LTD.
Block 2, Kaki Bukit Avenue 1, #04-01 to #04-04
Kaki Bukit Industrial Estate, Singapore 417938
Telephone: (65)7458910, Fax: (65)7418201

Quality, technology, and service are part of every product.

TPMH9004E01
MAY 1999 WT
Printed in Japan (300)