RCA

7029

MULTIPLIER PHOTOTUBE

Semitransparent Cathode On Reflective Substrate	**10-Stage, Dormer-Window Type S-17 Response**	**3.75" Max. Length 1.56" Max. Diameter**

TENTATIVE DATA

RCA-7029 is a sturdy, dormer-window type of multiplier phototube intended for use in the detection of low-level light signals in the presence of relatively high background illumination. It is, therefore, especially suited for low-contrast applications.

Outstanding features of the 7029 are its median cathode sensitivity of 125 microamperes per lumen and its stabilized sensitivity. Other distinguishing features include a dormer window through which light is directed onto a semitransparent photocathode located on the inner spherical surface at the end of the bulb; and 10 electrostatically focused multiplying (dynode) stages having stabilized secondary-emission characteristics.

The spectral response of the 7029 covers the range from about 2900 to 6200 angstroms as shown in Fig. 1. Maximum response occurs at approximately 4900 angstroms.

The 7029 is capable of very short time-resolution. For an input pulse having a duration of 1 millimicrosecond or less, the time spread of the pulse at the anode is less than 5 millimicroseconds measured at 50 per cent of the maximum pulse height.

DATA

General:

Spectral Response	S-17
Wavelength of Maximum Response	4900 ± 500 angstroms

Cathode, Semitransparent on Reflective Substrate:

Shape	Rectangular on concave spherical surface	
Minimum projected length on plane of window	0.65	in.
Minimum projected width on plane of window	0.5	in.

Direct Interelectrode Capacitances (Approx.):

Anode to dynode No.10	4	μμf
Anode to all other electrodes	7	μμf

Maximum Overall Length	3.75"
Maximum Seated Length	3.25"
Length From Base Seat to Center of Window Area	2.69" ± 0.19"
Diameter	1.50" ± 0.06"
Bulb	T-12 With Special End Contour
Base	Ultrashort Small-Shell Duodecal 12-Pin (JETEC No. B12-186), Non-hygroscopic
Socket	Eby No. 160, or equivalent
Operating Position	Any

Maximum Ratings, *Absolute Values:*

For Altitudes up to 60,000 Feet

ANODE-SUPPLY VOLTAGE (DC or Peak AC)	1250 max.	volts
SUPPLY VOLTAGE BETWEEN DYNODE No.10 AND ANODE (DC or Peak AC)	250 max.	volts
DYNODE-No.1 SUPPLY VOLTAGE (DC or Peak AC)	300 max.	volts
AVERAGE ANODE CURRENT●	20 max.	μa
AMBIENT TEMPERATURE RANGE	-50 to +75	°C

Characteristics Range Values for Equipment Design:

Under conditions with supply voltage (E) across voltage divider providing 1/11 of E per stage.

With E = 1000 volts (except as noted)

	Min.	*Median*	*Max.*	
Sensitivity:				
Radiant, at 4900 angstroms	-	27200	-	μa/μw
Cathode Radiant, at 4900 angstroms	-	0.085	-	μa/μw
Luminous♦	10	40	300	amp/lumen
Cathode Luminous:				
With tungsten light source▲	100	125	-	μa/lumen
With blue light source (See Fig.2)⊕	0.006	-	-	μa
Current Amplification	-	320000	-	
Equivalent Anode-Dark Current Input♦□	-	4×10^{-10}	-	lumen
Equivalent Noise Input★	-	1.1×10^{-11}	-	lumen

● Averaged over any interval of 30 seconds maximum.

♦ For conditions where the light source is a tungsten-filament lamp operated at a color temperature of 2870° K. A light input of 1 microlumen is used. The load resistor has a value of 0.01 megohm.

▲ For conditions the same as shown under (♦) except that the value of light flux is 0.001 lumen and 100 volts are applied between cathode and all other electrodes connected together as anode.

⊕ Under the following conditions: Light incident on the cathode is transmitted through a blue filter (Corning Glass Code No.5113 polished to 1/2 stock thickness) from a tungsten-filament lamp operated at a color temperature of 2870° K. The value of light flux on the filter is 0.001 lumen. The load resistor has a value of

0.01 megohm, and 100 volts are applied between cathode and all other electrodes connected together as anode.

♧ Measured at a tube temperature of 25° C and with the supply voltage (E) adjusted to give a luminous sensitivity of 20 amperes per lumen. Dark current caused by thermionic emission and ion feedback may be reduced by the use of a refrigerant.

□ For maximum signal-to-noise ratio, operation with a supply voltage (E) below 1000 volts is recommended.

★ Under the following conditions: Supply voltage (E) is 1000 volts, 25° C tube temperature, ac-amplifier bandwidth of 1 cycle per second, tungsten light source at color temperature of 2870° K interrupted at a low audio frequency to produce incident radiation pulses alternating between zero and the value stated. The "on" period of the pulse is equal to the "off" period. The output current is measured through a filter which passes only the fundamental frequency of the pulses.

SPECIAL PERFORMANCE DATA

4-Hour Stability Life Performance:

This test is performed on each 7029. Before this test is made, the tube is kept in total darkness for 24 hours. Under conditions with supply voltage E of 1000 volts, tube temperature of 25° C, and light flux adjusted to give an anode current of 10 microamperes within 1 minute after turning on light source, the tube is operated for 4 hours. At the end of this period the anode current will not increase by more than 1 microampere nor decrease by more than 1.5 microamperes.

DEFINITIONS

Radiant Sensitivity. The quotient of output current by incident radiant power of a given wavelength, at constant electrode voltages.

Cathode Radiant Sensitivity. The quotient of current leaving the photocathode by incident radiant power of a given wavelength.

Luminous Sensitivity. The quotient of output current by incident luminous flux, at constant electrode voltages.

Cathode Luminous Sensitivity. The quotient of current leaving the photocathode by the incident luminous flux.

Current Amplification. Ratio of the output current to the photocathode current, at constant electrode voltages.

Equivalent Anode-Dark-Current Input. The quotient of the anode dark current by the luminous sensitivity.

Equivalent Noise Input. That value of incident luminous flux which when modulated in a stated manner produces an rms output current equal to the rms noise current within a specified bandwidth.

GENERAL CONSIDERATIONS

The 7029 is a phototube incorporating an electron multiplier. An electron multiplier utilizes the phenomenon of secondary emission to amplify signals composed of electron streams. In the 7029 multiplier phototube, represented in Fig.3, the electrons emitted from the illuminated cathode are directed by fixed electrostatic fields to the first dynode (secondary emitter). The electrons impinging on the dynode surface produce many other electrons, the number depending on the energy of the impinging electrons. These secondary electrons are then directed by fixed-electrostatic fields along curved paths to the second dynode where they produce more new electrons. This multiplying process is repeated in each successive stage, with an ever-increasing stream of electrons, until those emitted from the last dynode (dynode No. 10) are collected by the anode and constitute the current utilized in the output circuit.

Dynode No. 10 is so shaped as to enclose partially the anode and to serve as a shield for it in order to prevent the fluctuating potential of the anode from interfering with electron focusing in the interdynode region. Actually the anode consists of a grating which allows the electrons from dynode No. 9 to pass through it to dynode No. 10. Spacing between dynode No. 10 and

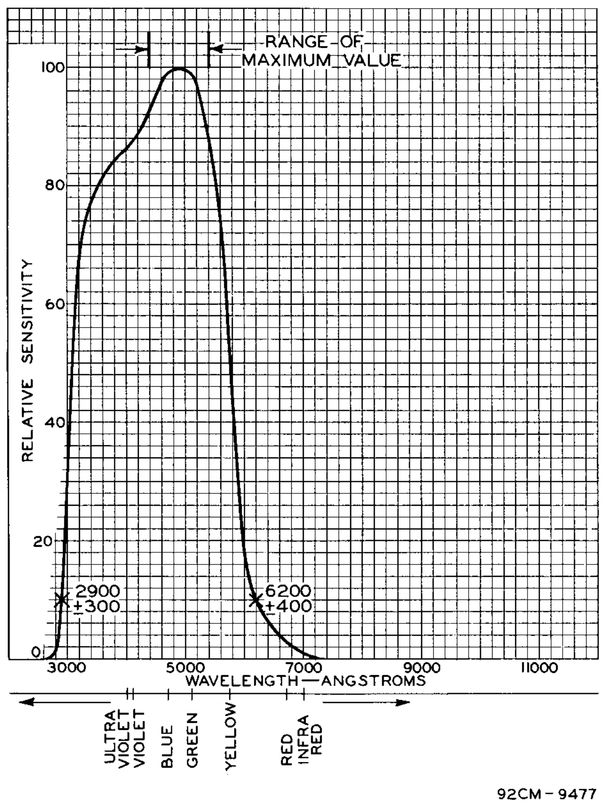


Fig. 1 - Tentative Spectral Sensitivity Characteristic of Type 7029 which has S-17 Response. Curve is shown for Equal Values of Radiant Flux at All Wavelengths.

anode creates a collecting field such that all the electrons emitted by dynode No. 10 are collected by the anode. Hence, the output current is substantially independent of the instantaneous positive anode potential over a wide range. As a result of this characteristic, the 7029 can be coupled to any practical load impedance. The metallic coating on the inner side wall of the glass bulb is connected to the cathode, and serves to direct the electrons from the cathode toward dynode No. 1.

The grill through which the electrons reach dynode No. 1, is connected to dynode No. 1 and serves along with the accelerating electrode as an electrostatic shield for the open side of the electrode structure.

INSTALLATION and APPLICATION

The *maximum ratings* in the tabulated data are limiting values above which the serviceability of the 7029 may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute ratings, the equipment designer has the responsibility of determining an average design value below each absolute rating by an amount such that the absolute values will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself. Care should be taken not to exceed the maximum ambient temperature of 75° C

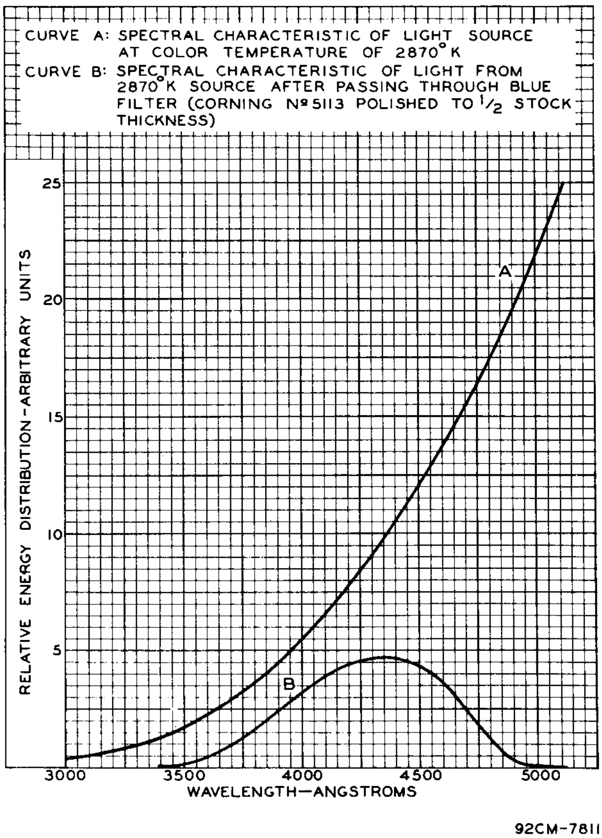


Fig.2 - Spectral Characteristic of 2870° K Light Source, and Spectral Characteristic of Light from 2870° K Source after Passing through Indicated Filter.

The *base pins* of the 7029 fit the duodecal 12-contact socket. The socket should be made of high-grade, low-leakage material, and should be installed so that the incident light falls on the dormer window of the tube. It is to be noted that the basing arrangement is such that the voltage between anode pin and adjacent pins is not more than twice the voltage per stage. As a result, external leakage between anode pin and adjacent pins is kept low.

In general, the *operating voltages* for the 7029 are as follows. The cathode-to-dynode-No. 1 potential is about the same as that applied between the successive dynodes. The steps for the successive stages are generally chosen as 75 to 125 volts. The voltage between dynode No. 10 and anode should be kept as low as will permit operation with anode-current saturation. Referring to the anode characteristic curves, shown in Fig.4, it will be seen that saturation occurs in the approximate range of 50 to 100 volts. Low operating voltage between dynode No. 10 and anode reduces the dark current. To obtain the indicated operating voltage between dynode No. 10 and anode, it will be necessary to increase the supply voltage between these electrodes above the operating voltage by an amount to allow for the signal-output voltage desired.

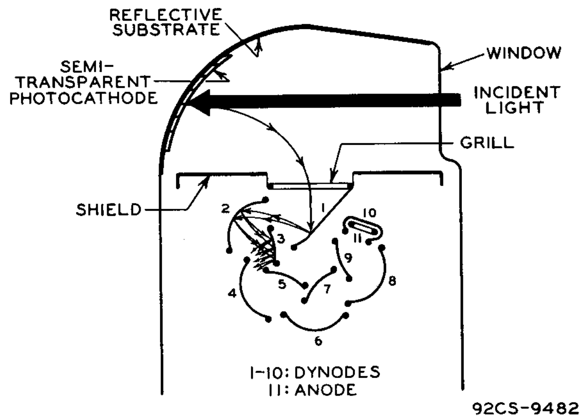


Fig.3 - Schematic Arrangement of Type 7029.

In applications where it is desired to keep the statistical fluctuations to a minimum, the potential between cathode and dynode No. 1 may be increased to the rated maximum value of 300 volts.

A very small *dark current* is observed when voltage is applied to the electrodes of the 7029 in complete darkness. This current has a component caused by leakage, and a component consisting of pulses produced by electrons thermionically released from the cathode, by secondary electrons released by ionic bombardment of the dynodes or cathode, or by cold emission from the electrodes. The magnitude of the dark current establishes a limit below which the exciting radiation on the cathode can not be detected.

When the application utilizes *continuous luminous excitation and dc anode current* and it is desired to have a high ratio of signal output to dark current, it is recommended that the operating supply voltage (E) be determined with reference to the curve in Fig.5 which shows the equivalent anode-dark-current input as a function of luminous sensitivity for the 7029, and the curves in Fig.6 which show luminous sensitivity as a function of the supply voltage.

In applications involving *pulsed excitation and ac coupling at the anode*, the best signal-to-noise ratio is obtained with a supply voltage (E) in the range from 750 to 1000 volts. Within this range, the noise at the anode is produced primarily by the statistical release of thermal electrons, and the noise power spectrum is essentially flat up to about 50 megacycles per second. At voltages above 1000 volts, regenerative phenomena usually contribute to the noise.

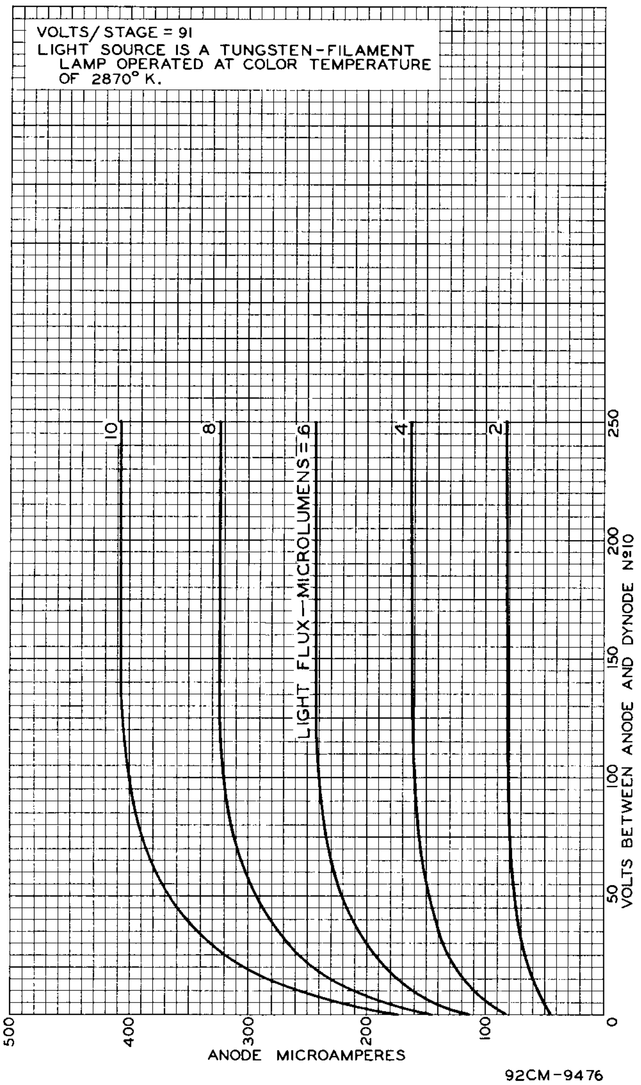


Fig.4 - Average Anode Characteristics of Type 7029.

The noise spectrum of the 7029 is such that the threshold of pulse detection depends on the associated circuitry. The bandpass filter should be designed to pass only the frequency range of the exciting signal in order to eliminate as much noise as possible.

In either dc or ac applications where maximum gain with unusually low dark current is required, the *use of a refrigerant*, such as dry ice, to cool the bulb of the 7029 is recommended. The refrigerant reduces the thermionic emission, and thereby lowers the detection threshold to give improved operation.

Exposing the 7029 to strong ultraviolet radiation may cause an increase in dark current. After cessation of such irradiation, the dark current drops rapidly.

The *operating stability* of the 7029 is dependent on the magnitude of the anode current and its duration. When the 7029 is operated at high values of anode current, a drop in sensitivity (sometimes called fatigue) may be expected. The extent of the drop below the tabulated sensitivity values depends on the severity of the operating conditions. After a period of idleness, the 7029 usually recovers a substantial percentage of such loss in sensitivity.

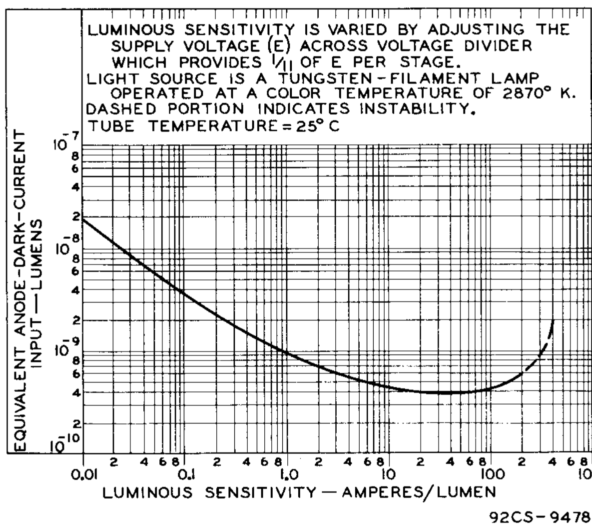


Fig.5 - Typical Anode-Dark-Current Characteristic of Type 7029.

The use of an average anode current well below the maximum rated value of 20 microamperes is recommended when stability of operation is important. When greater stability is required, the anode current should not exceed 10 microamperes.

The *range of sensitivity values* is dependent on the respective amplification of each dynode stage. Hence large variations in sensitivity can be expected between individual tubes of a given type. The overall amplification of a multiplier phototube is equal to the average amplification per stage raised to the *n*th power, where *n* is the number of stages. Thus, very small variations in amplification per stage produce very large changes in overall tube amplification.

Because these overall changes are very large, it is advisable for designers to provide adequate adjustment of the supply voltage per stage so as to be able to adjust the amplification of individual tubes to the desired design value. The voltage-adjustment range required to take care of variations between individual tubes may be determined from Fig.6. For example, if a sensitivity of 10 amperes per lumen is desired, it will be observed that this value on the "minimum" sensitivity curve corresponds to a supply voltage of 1000 volts, and on the "maximum" sensitivity curve to a supply voltage of about 700 volts. Therefore, provision should be made to adjust the supply voltage over the range from 700 to 1000 volts.

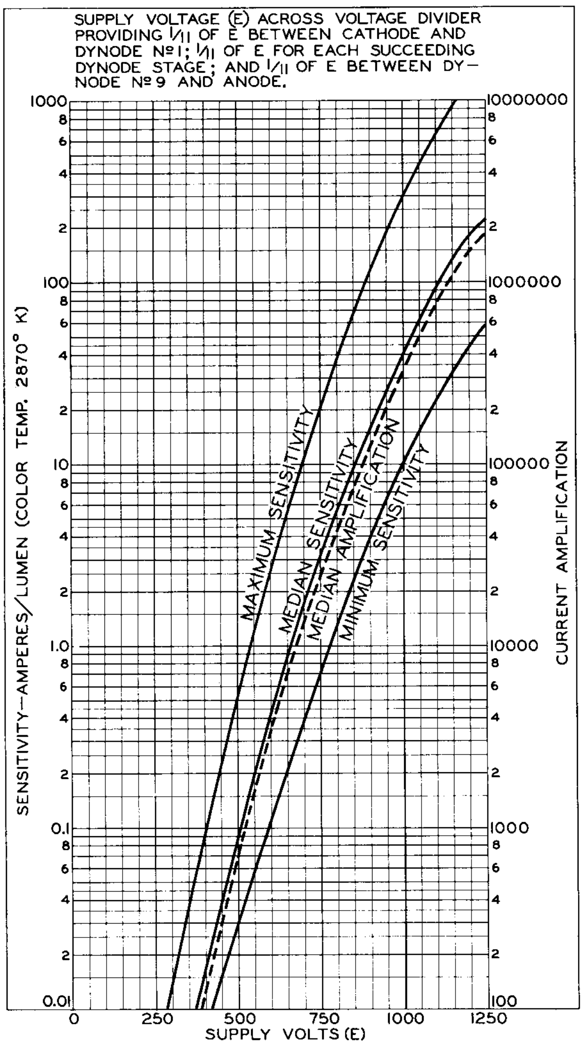


Fig.6 - Characteristics of Type 7029.

Electrostatic and/or magnetic shielding of the 7029 may be necessary. The metallic coating on the inner wall of the glass bulb acts as an electrostatic shield to prevent the coated portion of the bulb wall from charging to a positive potential. However, the uncoated area of the bulb wall tends to charge to a potential near that of the anode, especially when the 7029 is operated at voltages near the maximum, with the result that an internal discharge phenomenon may occur and cause an increase in noise. To prevent this possibility, it is suggested that a shield be closely fitted over the uncoated area and be connected as a safety precaution (see below) through a high impedance in the order of 10 megohms to a potential near that of the cathode. The shield may consist of a conductive

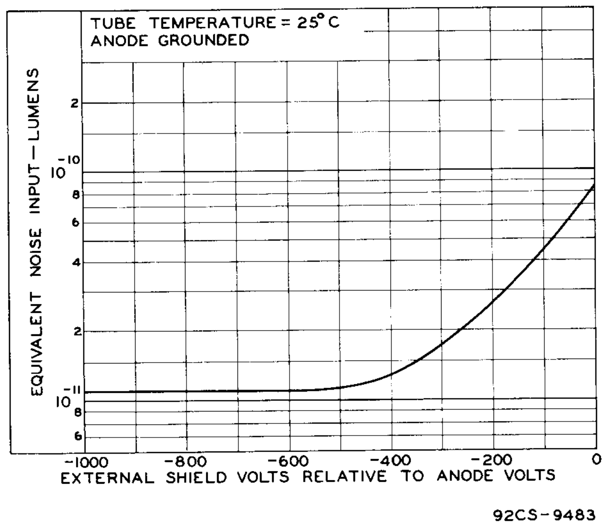


Fig.7 - Effect of External-Shield Potential on Equivalent Noise Input of Type 7029.

coating painted on the clear portion of the bulb or metallic foil wrapped around the clear area. The curve in Fig.7 illustrates the effect of shield potential on the equivalent noise input.

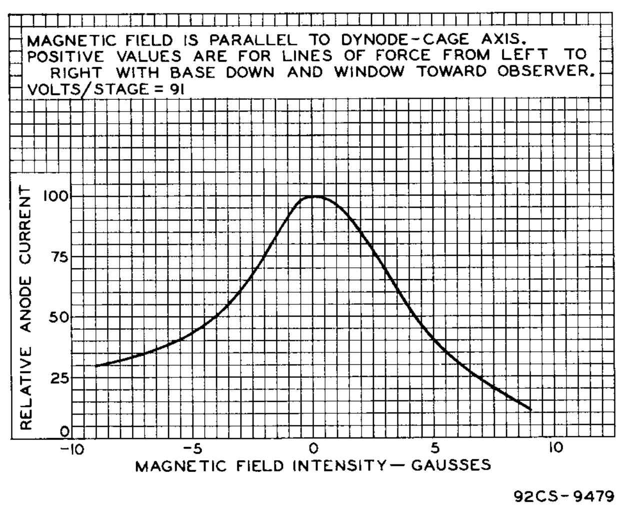


Fig.8 - Effect of Magnetic Field on Anode Current of Type 7029.

With certain orientations of the 7029, it will be observed that the earth's magnetic field is sufficient to cause a noticeable decrease in the response of the tube. The curve in Fig.8 shows the effect on anode current of variation in magnetic field strength under the conditions indicated. With increase in voltage above 100 volts between cathode and dynode No. 1, the effect of the magnetic field will cause less decrease in anode current.

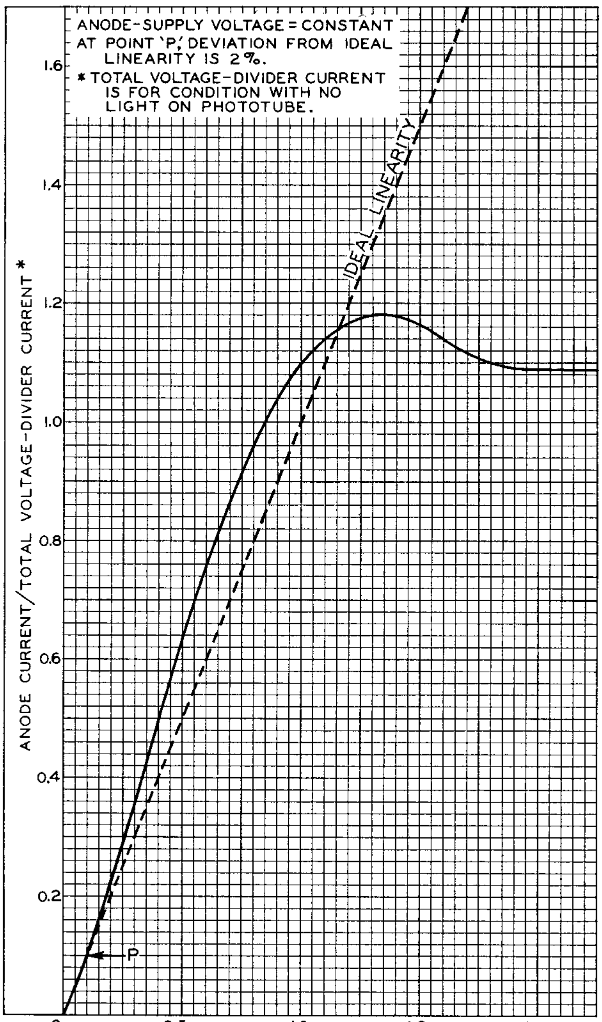


Fig.9 - Linearity Characteristic of Type 7029 as Affected by Ratio of Anode Current to Total Divider Current.

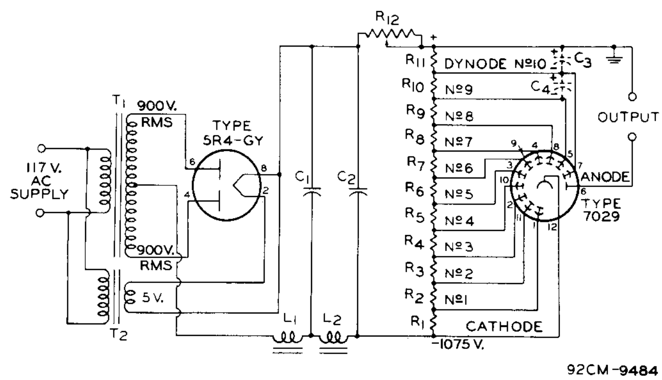
To prevent such decrease in response of the tube, magnetic shielding should be provided. When connected to cathode potential, this shielding may closely fit the bulb and serves the dual purpose of providing both magnetic and electrostatic shielding. When connected to anode potential, this shielding should be spaced at least 1/2 inch from the bulb wall to prevent the internal discharge phenomenon described above.

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

Adequate *light shielding* should be provided to prevent extraneous light from reaching any part of the 7029. Although the metallic coating on the inner wall of the glass bulb serves to reduce the amount of extraneous light reaching the electrodes, it is inadequate to shield completely the entire structure from extraneous light.

Whenever frequency response is important, the leads from the 7029 to the amplifier should be short so as to minimize capacitance shunting of the phototube load.

The *dc supply voltages* for the electrodes can be obtained conveniently from a high-voltage, vacuum-tube rectifier. The voltage for each dynode and for the anode can be supplied by spaced taps on a voltage divider across the rectified power supply. The current through the voltage divider will depend on the voltage regulation required by the application. In general,



C1 C2: 2 μf, 1000 volts (dc working)
C3 C4: 0.1 μf, 150 volts (dc working).
Required only if high peak currents are drawn.
L1 L2: United Transformer Corp. No.R-17, or equivalent
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10: 18000 ohms, 1 watt
R11: 12000 ohms, 1 watt
R12: 200000 ohms, 12 watts, adjustable, General Radio Type 471-A, or equivalent
T1: United Transformer Corp. No.S-45, or equivalent
T2: United Transformer Corp. No.FT-6, or equivalent

Fig.10 - Full-Wave Rectifier Power-Supply Circuit with Voltage Divider for Supplying DC Voltages to Type 7029 in Applications Critical as to Hum Modulation.

the current in the divider should be about 10 times the maximum value of total dynode current flowing through the divider. Such a value will prevent variations of the dynode potentials by the signal current. Because of the relatively large divider current required for good regulation, the use of a rectifier of the full-wave type is recommended. Sufficient filtering will ordinarily be provided by a well-designed two-section filter of the capacitor-input type. A choke-input filter may be desirable for certain applications to provide better regulation. Due to critical dependence of the gain of the 7029 on voltage, rapid changes in the voltage resulting from insufficient filtering of the power supply will introduce hum modulation; and slow shifts in the line voltage due to poor regulation will cause a change in the level of the output. When the dc supply voltage is provided by means of a rectifier, satisfactory regulation can be obtained by the use of a vacuum-tube regulator circuit of the mu-bridge type.

The relationship between the ratio of anode current-to-voltage-divider current and incident light flux is shown in Fig.9. For operation along the *ideal linearity* curve of Fig.9, the anode current-to-voltage-divider current ratio should be less than 0.1.

In most applications, it is recommended that the positive high-voltage terminal be grounded in order that the output signal will be produced between anode and ground. This method prevents power-supply fluctuations from being coupled directly into the signal-output circuit.

The high voltages at which the 7029 is operated are very dangerous. Care should be taken in the design of apparatus to prevent the operator from coming in contact with these high voltages. Precautions should include the enclosure of high-potential terminals and the use of interlock switches to break the primary circuit of the high-voltage power supply when access to the apparatus is required.

In the use of the 7029, as with other tubes requiring high voltages, it should always be remembered that these high voltages may appear at points in the circuit which are normally at low potential, because of defective circuit parts or incorrect circuit connections. Therefore, before any part of the circuit is touched, the power-supply switch should be turned off and both terminals of any capacitors grounded.

A typical power-supply circuit for the 7029 is shown in Fig.10.

REFERENCES

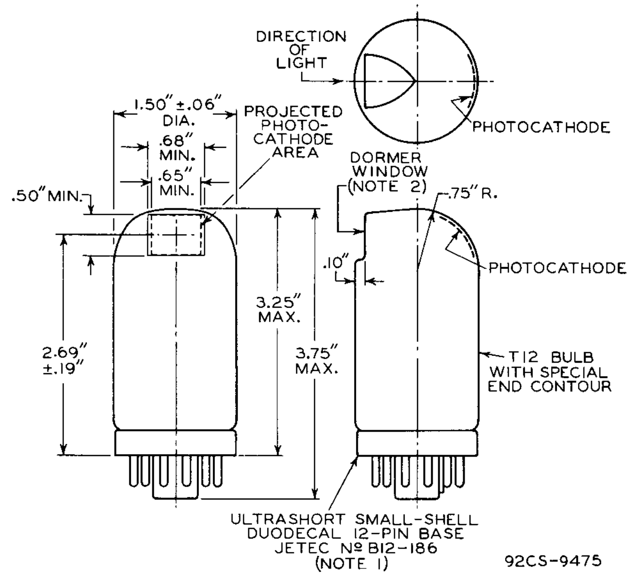
Ralph W. Engstrom, *"Multiplier Phototube Characteristics; Application to Low Light Levels,"* Journal of the Optical Society of America, Vol.37, pp.420-431, June, 1947.

F. V. Hunt and R. W. Hickman, *"On Electronic Voltage Stabilizers,"* Review of Scientific Instruments, Vol.10, pp.6-21, January, 1939.

R. W. Engstrom, R. G. Stoudenheimer, and A. M. Glover, *"Production Testing of Multiplier Phototubes Designed for Scintillation Counter Applications,"* Nucleonics, Vol.10, No.4, pp.58-62, April, 1952.

R. W. Engstrom, E. Fischer, *"Effects of Voltage-Divider Current Characteristics on Multiplier Phototube Response,"* Review of Scientific Instruments, Vol.28, No.7, July 1957.

DIMENSIONAL OUTLINE

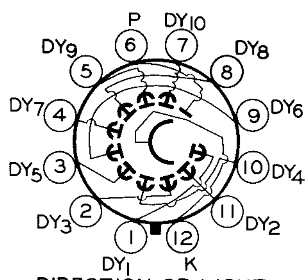


NOTE 1: ℄ OF BULB WILL NOT DEVIATE MORE THAN 2° IN ANY DIRECTION FROM THE PERPENDICULAR ERECTED AT THE CENTER OF BOTTOM OF THE BASE.

NOTE 2: DORMER WINDOW IS ON OPPOSITE SIDE OF TUBE FROM BASE KEY.

SOCKET CONNECTIONS
Bottom View

PIN 1: DYNODE No.1
PIN 2: DYNODE No.3
PIN 3: DYNODE No.5
PIN 4: DYNODE No.7
PIN 5: DYNODE No.9
PIN 6: ANODE



PIN 7: DYNODE No.10
PIN 8: DYNODE No.8
PIN 9: DYNODE No.6
PIN 10: DYNODE No.4
PIN 11: DYNODE No.2
PIN 12: CATHODE

DIRECTION OF LIGHT: INTO DORMER WINDOW

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