Correspondence

Regulation of the Individual Dynode Voltages for Photomultiplier Tubes*

The above paper by Harris and Flagge[1] presents a very clear and complete exposition of various means for regulating the dynode voltage against dynode current changes and, to some extent, power supply changes when the photomultiplier is used at relatively low frequencies or with relatively long rise time pulses. However, two very important effects associated with the use of Zener diodes with photomultipliers have not been mentioned.

The first effect is that of temperature coefficient of the diodes. Table I shows some data taken at this institution on several Texas Instrument diodes. It will be noted that the temperature coefficient for diodes of this voltage range is of the order of 0.1 per cent per°C. This means that when such a set of diodes is installed on a typical photomultiplier socket where temperature variations are bound to occur, some effect due to temperature coefficient will be felt. As a matter of fact, it is difficult to see how one can guarantee less than a 10°C temperature change from day to night, for example. This would result in 1 per cent dynode voltage change. The effect of this dynode voltage change is, of course, that the excellent current regulating characteristics of the Zener diode are completely obliterated by this temperature-induced voltage change insofar as the gain of photomultiplier is concerned. Of course, there is a way out, namely, to temperature-regulate the diodes alone or the entire assembly.

TABLE I

Diode	Op. Current	App. Drop, Volts	T.C. %/°C
618C No. 1	0.2 ma	113	+0.136
No. 2	0.2 ma	119	+0.151
No. 3	0.2 ma	92	+0.110
622C No. 1	0.2 ma	225	+0.061
No. 2	0.2 ma	256	+0.105
No. 3	0.2 ma	233	+0.092

The second difficulty is that in applications involving fast scintillators, the ac impedance of silicon diodes is not sufficiently low so that it becomes necessary to by-pass the Zener diode with a capacitor. In tubes such as the 6810 the problem then arises of providing sufficient charging current for the capacitor between pulses so as to keep the average voltage level constant. Presently available high-voltage Zener diodes do not have sufficient dissipation capability to permit an adequately high static current being passed through them to provide this charging current.

While difficulties have been pointed out for Zener diodes, they exist in a varying degree for other types of diodes such as the NE-2 or the 5651. With the latter tube, some of the current limitations become less severe; however, size and temperature coefficient problems are more accentuated.

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Author's Comment[2]

Mr. Enslein's comments warrant further discussion and consideration.

The regulator circuit[3] does, in our experience, if properly designed, provide very good regulation against power supply changes.

We have not found the use of this regulator circuit to be restricted to relatively low frequencies nor to relatively long rise time pulses. It has been used by the author with pulse periods in the millimicrosecond range. The limiting factor is found to be the final anode-to-ground capacitance. The only defense against this difficulty is the use of a low-value resistor for the anode load which is consistent with a compromise between desired pulse height and pulse period.

It is true that the temperature coefficient for Zener diodes was not mentioned in the paper, but the authors were not unaware of this effect. In fact, Mr. Flagge, in some of his work, found that, by proper choice of gas tubes and silicon Zener diodes having temperature coefficients opposite in sign, and by judicious placement in the network, he could obtain a regulator almost independent of temperature changes. Three graphs of his data are included to show how these effects can be made to compensate each other. (See Fig. 1.)

Relative to the necessity for by-passing the diodes with capacitor, I can only say that I have never found this to be necessary. Of course, the diodes themselves provide inherent shunting capacitance of up to ten or more picofarads, but if the use of additional capacitance becomes necessary, the required dissipation can be obtained by using lower voltage diodes in series. This latter alternative is more expensive, of course, but can be used where the need justifies the cost.

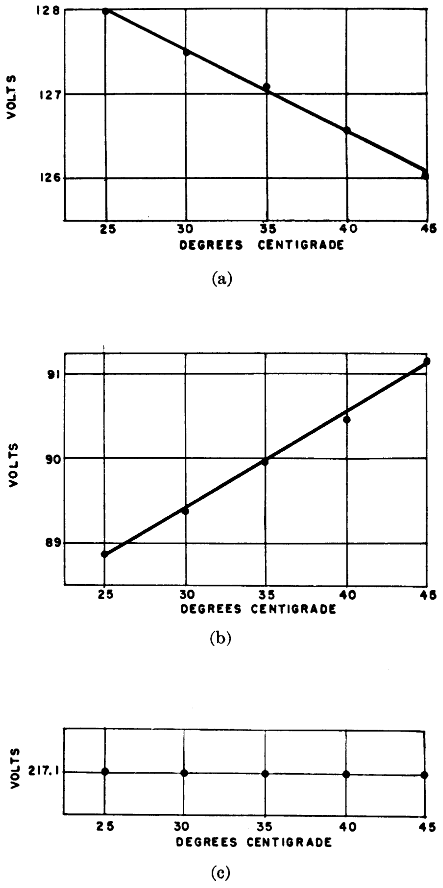

Fig. 1—Voltage-temperature characteristics of individual voltage regulating devices. (a) Two neon tubes in series. (b) One silicone junction diode. (c) Two neon tubes and one diode in series.

There is another difficulty to be avoided which Mr. Enslein did not mention. If one is not careful to insure that the diodes operate at current values well above the Zener knee, the photomultiplier tube noise may become quite high due to diode noise generated in the knee region. The minimum current value for low-noise output varies greatly between diodes and it is sometimes necessary to select diodes for best performance. One of the most troublesome effects of this phenomenon is that the diodes can break into and out of this high-noise region rather abruptly, as diode current changes occur in response to load changes, causing spurious effects. However, the designer can easily avoid this trouble by exercising suitable care in his choice of circuit components.

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[1] O. R. Harris and B. Flagge, IRE Trans. on Nuclear Science, vol. NS-4, pp. 3–11; March, 1957.

[2] Received by the PGNS, March 6, 1958.

[3] Harris and Flagge, *op. cit.*, Fig. 5, p. 6.