Low-Temperature Operation of the Preamplified Spiraltron* Electron Multiplier Model 4219-X

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By:

W. G. Wolber, Senior Staff Engineer
Bendix Research Laboratories
Southfield, Michigan 48075

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Electro-Optics Division

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In laboratory experiments conducted at cryogenic temperatures, a Channeltron® or Spiraltron detector for charged particles or energetic radiation must often operate in a vacuum environment as well as at low temperatures. Heating an insulated detector may not be a practical alternative, since this is always cumbersome. To determine the performance characteristics of an unheated detector under cryogenic conditions, Dr. Robert Gomer† and Dr. Colin Lea† recently evaluated the new Model 4219-X Spiraltron electron multiplier (Figure 1) at room temperature (300°K), 78°K, and 20°K.* Care was taken to minimize thermal shock to the detector, and no mechanical problems were encountered during testing; the detector operated at its nominal performance after returning to room temperature.

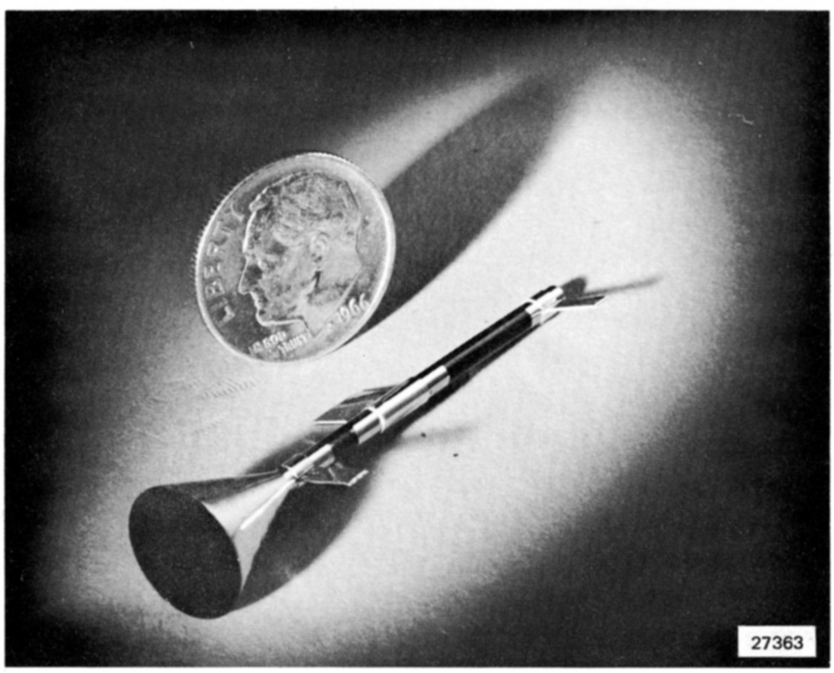

Figure 1 - Photograph of Model 4219-X Spiraltron Electron Multiplier

†The James Franck Institute, University of Chicago.

*Dr. Gomer and Mr. Thomas Engel have previously evaluated standard Channeltron detectors at these temperatures. Their unpublished data are consistent with the results reported in this paper.

Probably the most significant effect reported by Gomer and Lea was a dramatic change in resistance with temperature. Figure 2 shows the resistance as a function of reciprocal absolute temperature in a semi-logarithmic plot. The curve is seen to be similar to those typical for high-resistance semiconductors, such as thermistors. The data points obtained at the three temperatures are also listed in Table 1.

Table 1 - Model 4219-X Resistance as a Function of Temperature

Temperature, °K	Preamplifier Resistance, ohm	Spiraltron Resistance, ohm
300	2.95×10^{8}	7.4×10^{8}
78	1.2×10^{10}	5.3×10^{10}
20	5.5×10^{13}	3.2×10^{14}

Figures 3, 4, and 5 show Spiraltron gain as a function of total voltage at high output currents for the three temperatures. Equipment limitations precluded operation in the pulse-counting mode, as well as examination of operation at lower output currents. Nevertheless, the data obtained define the limits of low-temperature operation and illuminate the direction future development should take to relieve these limits.

It is well known that the average analog gain of a channel multiplier begins to fall off as the output current approaches the channel current. Typically, this effect [which also can be seen as a change in the constancy of I_{out}/I_S ($E_S = K$), where E_S is the Spiraltron voltage], becomes noticeable when I_{out}/I_S is about 0.1, where I_S is the Spiraltron current. A similar effect is seen in pulse-saturated operation; gain is seen to decrease as a function of increasing pulse rate.[1-3]

If we examine Figures 3 through 5, we see that for input currents of 10^{-11} to 10^{-12} amp, the "flattening" of the gain versus E_T curve occurs in roughly the same voltage range for all three temperatures, whereas the gain of the device in this range is drastically reduced as temperature drops. At first glance, one might conclude that gain is affected by temperature; but a closer examination shows that the data neither support nor preclude this conclusion. However, the steep slope of the log I versus E curve at lower voltages, which is seen for all three temperatures, would seem to indicate that this supposed effect is not probable.

If we compute the $I_o = 0.1$ (I_S) condition at $E_S = 2000$ V for the three temperature cases, as has been done in Table 2, we see that the values of I_o obtained agree reasonably well with the curve "flattening" seen. Therefore, the low gain seen at low temperature and high output

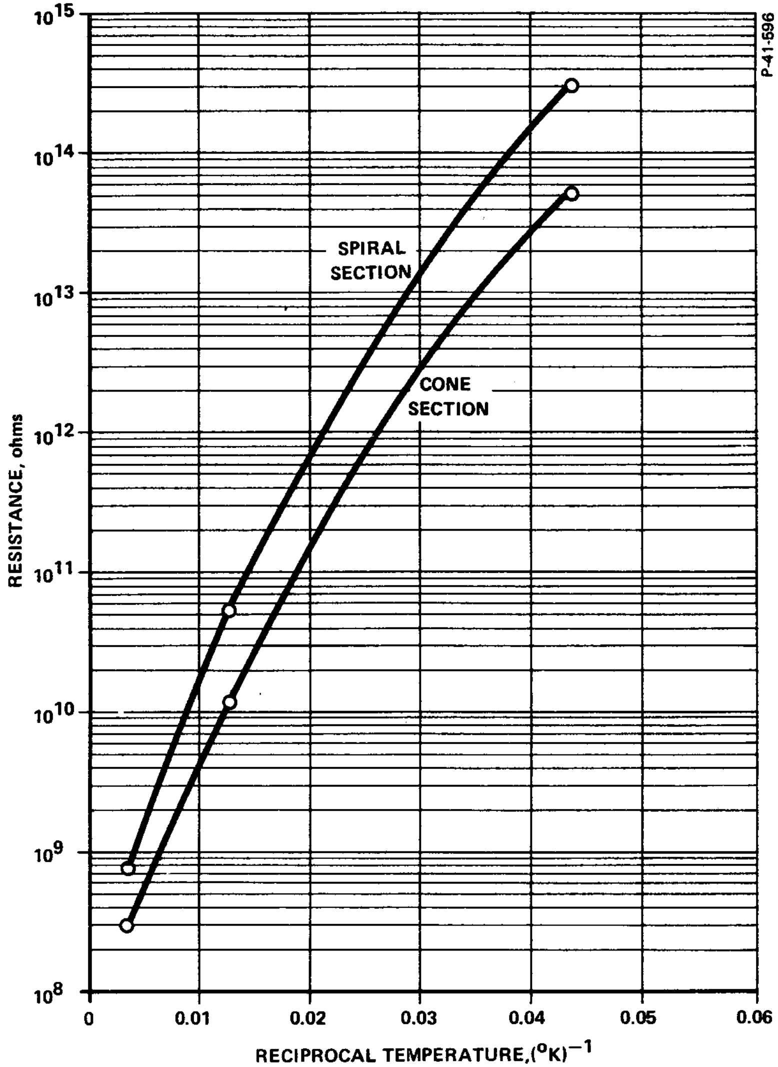

Figure 2 - Model 4219-X Resistance Versus Reciprocal Absolute Temperature

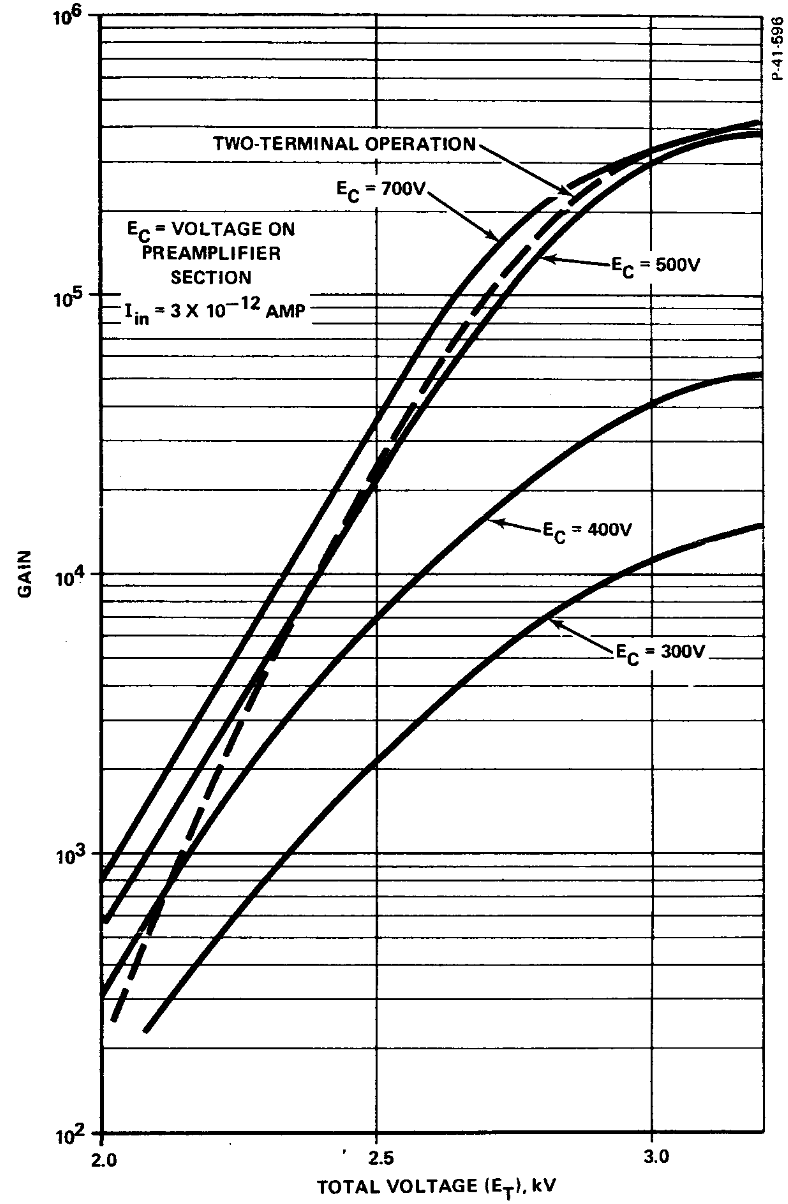

Figure 3 - Average Gain Versus Voltage of Model 4219-X at 300°K

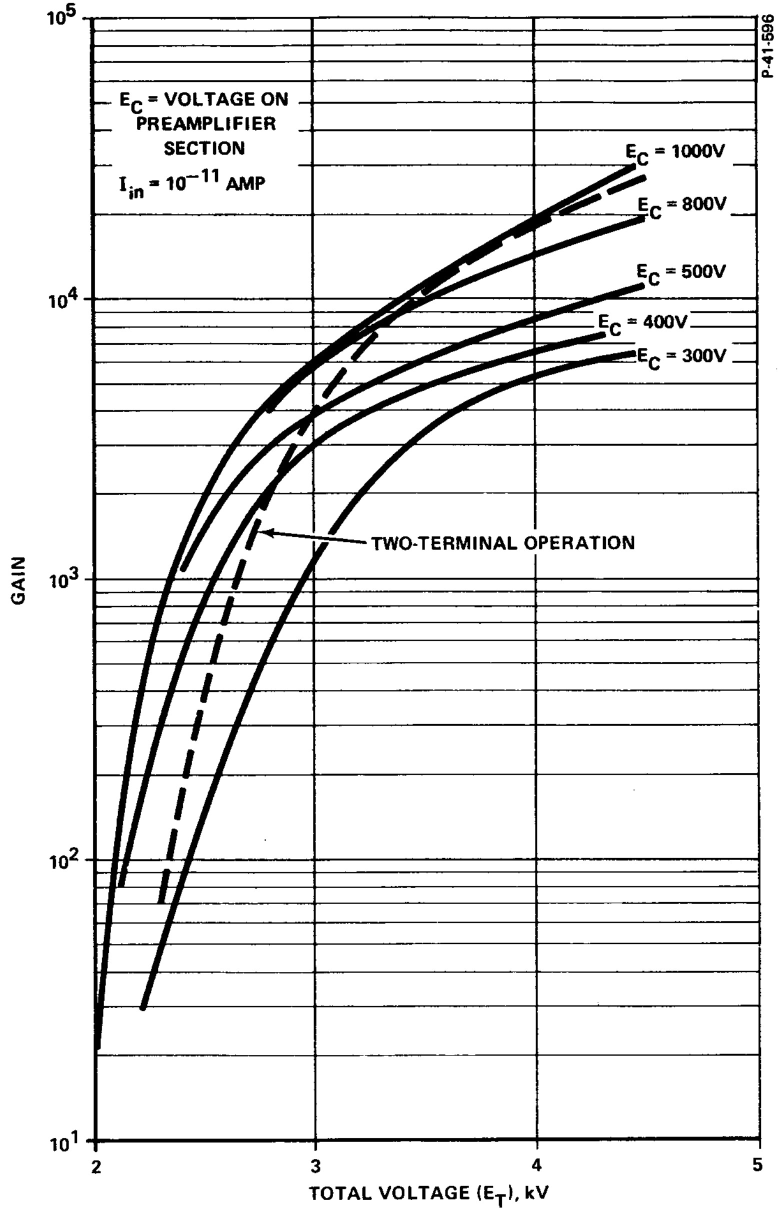

Figure 4 - Average Gain Versus Voltage for Model 4219-X at 78°K

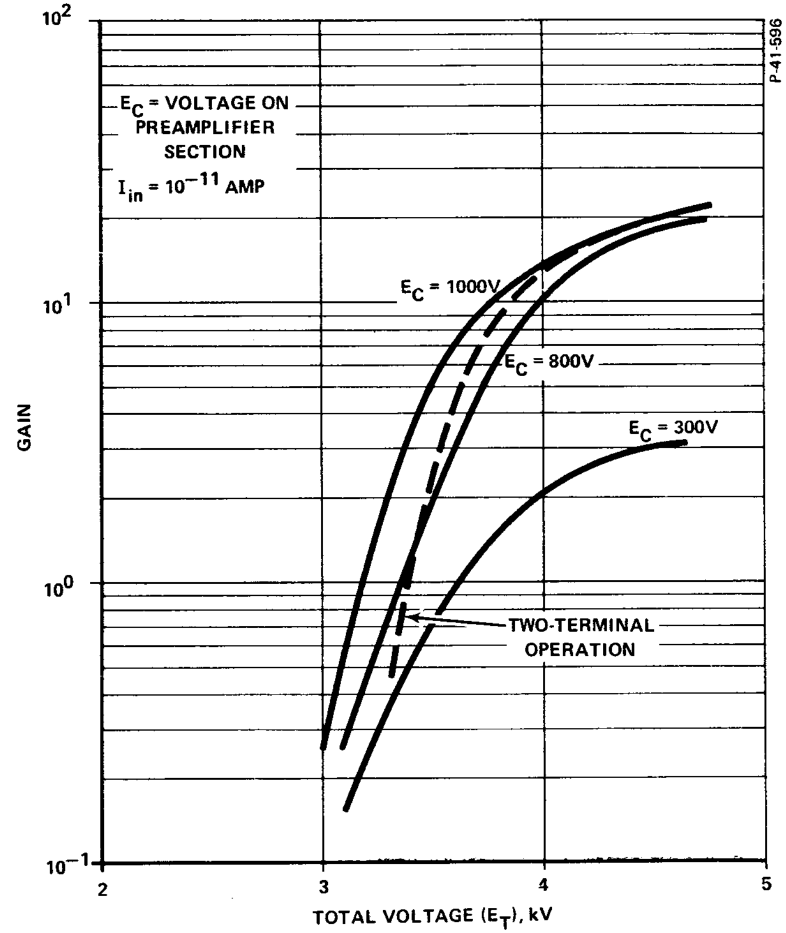

Figure 5 - Average Gain Versus Voltage for Model 4219-X at 20°K

current is undoubtedly due to reversible current saturation gain depression, caused by the change in Spiraltron resistance and consequently Spiraltron current.

Table 2 - "Limiting" Output Current at E_S = 2000 Volts

Temperature, °K	R_S, ohm	I_S, amp	$I_o = I_L = 0.1\ I_S$ (amp)
300	7.4×10^{8}	2.7×10^{-6}	2.7×10^{-7}
78	5.3×10^{10}	3.8×10^{-8}	3.8×10^{-9}
20	3.2×10^{14}	6.2×10^{-12}	6.2×10^{-13}

Based upon these considerations, we can state with some confidence that the Model 4219-X is likely to be useful for analog operation at 80°K up to an output current of 5×10^{-9} amp, and that pulse-mode operation is feasible at pulse rates lower than 10^4 counts per second. Operation at 20°K, however, is very limited. Probably the only useful mode of operation at this temperature would be the pulse mode at very low count rates, on the order of less than 20 counts per second.

To improve operation at the lower temperatures, the resistance of the Spiraltron section must be lowered. A special design for low-temperature operation is a likely interim solution, since it appears that obtaining a device whose resistance is less sensitive to temperature is a long-range task. The amount of resistance change required implies new materials, so that progress toward the goal of a low-temperature Spiraltron electron multiplier with conventional performance will be paced by materials development.

To summarize, Gomer and Lea found the following:

(1) No mechanical problems in subjecting the Model 4219-X to 20°K, and no permanent functional changes

(2) An increase in the resistance of the detector as the temperature is lowered

(3) A decrease in the linear operating range of the detector as the temperature is lowered; moderate at 78°K and very severe at 20°K.

REFERENCES

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