duced at a distance R from the anode does not suffer attachment on its way to the counter anode ($R=R_I$) is then given by

$$P(R)=\exp\left\{-n(T)\int_{R}^{R_I} Q(E)\frac{U}{W}dr\right\},$$

$n(T)$ being the density of iodine, $Q(E)$ the cross section for dissociative attachment at an electron energy E, U the average random velocity, and W the average drift velocity of electrons in the counter. Since in all cases the partial pressure of iodine is very small compared with the buffer gas pressure, U and W are given by the buffer gas data.[5] The efficiency of a uniformly irradiated counter is then

$$\epsilon=\eta A(T)\frac{\int_{R_I}^{R_A} 2\pi r P(r)dr}{\int_{R_I}^{R_A} 2\pi r dr},$$

where $\eta=42\%$ is the photoionization efficiency of iodine,[2] R_A the cathode radius, and $A(T)$ a factor allowing for a temperature-dependent uv absorption by the iodine

$$A(T)=1-\exp[-\sigma l n(T)],$$

σ being the uv absorption cross section of iodine,[2] and l the length of the counter.

The integrations were carried out numerically using a 10-point polynomial interpolation of the discrete experimental values of n, U, W, Q. A counter of 35 mm length with an anode of 1.5 mm diam and a cathode of 20 mm diam filled with buffer gas at 400 mm Hg pressure was considered.

Figure 1 shows the "across-tube" response to normally incident radiation. The right part of the figure shows $P(R)$ for helium (full curves) and argon (broken curves) with the temperature as a parameter. Higher temperatures give a lower counting efficiency but an improved suppression of photoelectrons from the counter wall. The difference between argon and helium[6] is due to the higher random velocities of electrons in argon which lead to lower attachment cross sections. The left part of the figure shows $P(R)$ for helium with the counter voltage as a parameter.

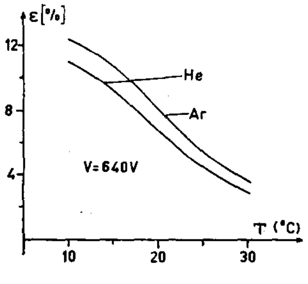

FIG. 2. Temperature dependence of the counting efficiency. (To be compared with Fig. 4 of Brackmann *et al.*[2])

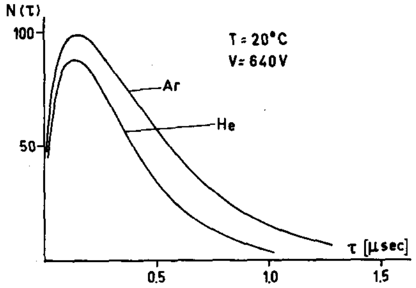

FIG. 3. Delay time distribution of an iodine counter. The vertical scale is in arbitrary units.

Higher operating voltages extend the sensitive volume of the counter thus giving rise to a "plateau slope" of 20%/100 V even under ideal geometrical conditions.

Figure 2 shows the temperature dependence of the efficiency of a uniformly irradiated counter. Two mutually opposing effects are involved. With increasing temperature we have a greater light absorption due to the higher iodine pressure. This gives an improved counting efficiency. On the other hand more electrons are lost by attachment. This second process is, by far, the more important one.

Figure 3 shows the delay time distribution $N(\tau)$ of a uniformly irradiated counter,

$$N(\tau)=2\pi R(\tau)P[R(\tau)],\quad \tau=\int_{R}^{R_I}\frac{dr'}{W}.$$

Though argon provides better sensitivity[6] the helium curve is considerably narrower (FWHM). This will favor use of helium in counters for coincidence experiments.

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Simple Optical Dewar and Photomultiplier Cooler

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THIS note describes an optical Dewar and a photomultiplier cooler which can be easily constructed from inexpensive parts.

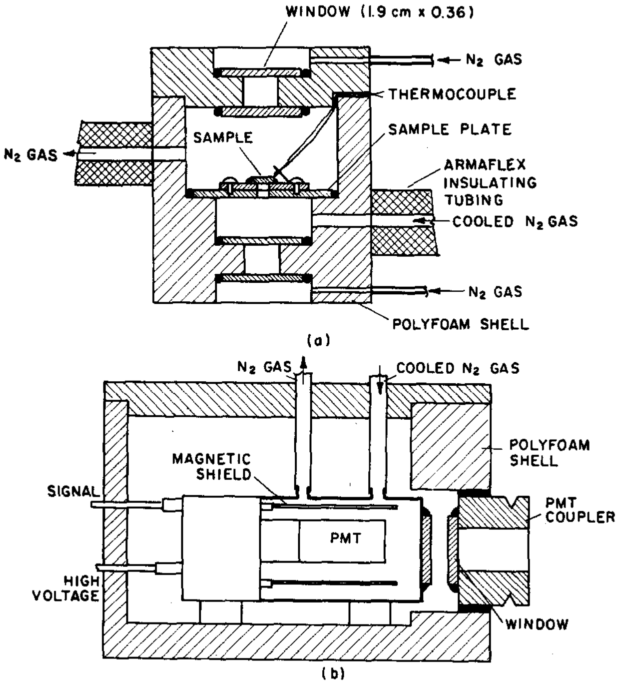

FIG. 1. Cross section view of (a) simple flow Dewar and a (b) simple photomultiplier cooler.

Magneto-optical effects and other optical properties of materials are usually studied as a function of temperature in the visible and infrared spectral regions. The optical flow Dewar system described here is suitable for such investigations. It is simple, inexpensive, and can be assembled within a day.

A conventional flow Dewar system consists of a four- or two-window stainless or glass Dewar, a liquid nitrogen exchange reservoir (a coil of copper tubing inserted in liquid nitrogen), a heater (a Nichrome wire, 300 Ω), and a feedback temperature controller or a Variac. The connecting hose is thermally insulated with Armaflex tubing or a similar material. Nitrogen gas, under a pressure of $\sim$0.2–1.4 kg/cm^2, is first cooled by passing it through the exchange reservoir and then is raised to the desired temperature by the heater. Operating temperatures in the range of -160 to 100°C with regulation in the order of 0.25 C° may be maintained for hours by the use of this system.

The same results were obtained when the glass flow Dewar was replaced with a Polyfoam Dewar. The Dewar, shown in Fig. 1(a), consists of a Polyfoam body shaped from an acid container or a picnic food cooler. NaCl, sapphire, quartz, and glass windows were used successfully for different spectral regions. The NaCl windows were pitted from water vapor after extended use, but they may be readily replaced. The windows are cemented on the inside and outside of each half of the body of the Dewar with silicone rubber cement. The air pockets between each pair of windows act as a partial vacuum as the temperature is lowered. Four thin-wall stainless steel tubes are inserted and cemented into the body—two act as the input and output of the cooled nitrogen gas; the other two are used to keep the outer windows clear of condensation by a slow, flow of nitrogen gas. The sample is mounted on a copper plate with the use of vacuum grease, silicone cement Glyptal, or masking tape. This plate is, in turn, screwed to a slotted base plate which is permanently fixed to the lower half of the Dewar. The top and bottom sections of the Dewar are held together with a layer of vacuum grease and electrical tape. The thermocouple is pressed to the surface of sample by a Teflon strip. The Polyfoam Dewar is then flushed for approximately 30 min with nitrogen gas before cooling in order to drive out any trapped air.

This Dewar can easily be placed under a microscope, between pole faces, or in a conventional optical setup. It has been used to investigate magnetic domains and Faraday rotation as a function of temperature. A similar Dewar is being used to study the recombination radiation from Gunn and avalanche processes in GaAs as a function of temperature.

The need for cooling sensitive photomultiplier tubes (PMT) in detecting weak light signals is well known. The PMT cooler described here is inexpensive and readily adapted for any PMT assembly.

The cooler, shown in Fig. 1(b) consists of a Polyfoam body shaped from an acid container and a modified PMT housing. The system is cooled by a flow of cooled nitrogen gas.

The Polyfoam shell is cemented with silicone rubber cement and electrical tape. Two metal tubes are inserted in the shell for the inlet and outlet of the cooled nitrogen gas. A PMT coupler is cemented and taped to the Polyfoam shell in order to mount the cooler to a spectrometer. Two inlet and outlet tubes are inserted in the PMT housing, and rubber tubing is used to connect the shell to the housing. A window is cemented with silicone rubber cement onto the housing and on the inside of the coupler.

The PMT and housing is installed within the shell and firmly held with Polyfoam sections. The housing is then surrounded with Polyfoam chips for added insulation. The top and bottom of the cooler are held together with a layer of vacuum grease and tape. Nitrogen gas is flushed through the system for approximately 30 min to drive out any air trapped within the PMT housing. The interchamber between the shell and the PMT housing acts as a partial vacuum as the temperature is lowered. Very little condensation was observed on the outer and inner windows. If there is any condensation, it would appear on the housing or on the PMT electrostatic and magnetic shield since they are cooled first.

Within 30 min of inserting nitrogen gas under a pressure of $\sim$0.2 kg/cm^2 which was cooled through an exchange reservoir, the dark current of an RCA 7102(S-1) biased at 1000 V was reduced by a factor of 10^4, and that of an EMI 9558(S-20) biased at 1500 V was reduced by 10^2. The photocathode temperature of the 7102 was approximately $-60°C$. It was found that cooling the EMI tube too far below $-9.5°C$ resulted in irregular bursts of large voltage pulses. To eliminate these bursts, we regulated the cooling rate. The temperature of the output N_2 gas from tube was $\sim -7°C$.

The author wishes to express his appreciation to N. Yurlina for constructing the Dewars and coolers, and to J. Maggio for mounting the samples.

Measurement of Small dc Voltages Using Phase Sensitive Detection Techniques*

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CLARKE[1,2] and McWane *et al.*[3] have developed circuits which make use of quantum interference devices based on Josephson tunnelling for the measurement of small dc voltages ($\sim 10^{-14}-10^{-15}$ V) across low resistances ($<10^{-8}\ \Omega$) at liquid helium temperatures. This note describes a potentiometer (shown in Fig. 1) which uses a similar low temperature circuit but utilizes current modulation and standard phase sensitive detection techniques to sense small changes in the critical current of Clarke's double Josephson junction device. The ac detection scheme facilitates the use of current feedback, which reduces the overall time constant of the circuit, by transformer coupling the output of the double junction device to the feedback amplifier (phase sensitive detector). This eliminates troublesome ground loop problems associated with current feedback by isolating the double junction device from the feedback amplifier.

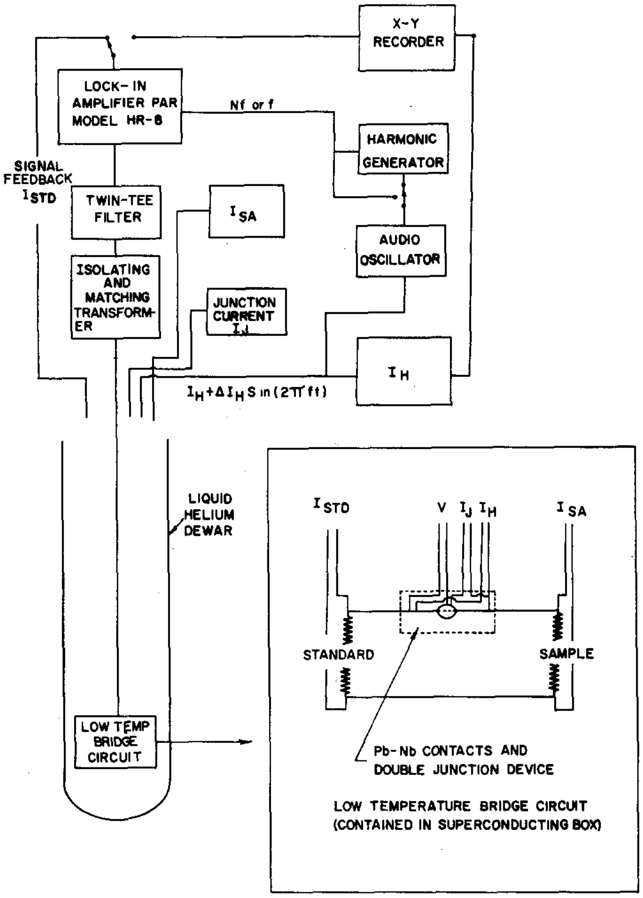

FIG. 1. Schematic diagram of the potentiometer circuit. The modulation current is added at a frequency of 100 Hz (f_0) and the twin T filter included in the input circuit for the phase sensitive rejects the signal at 100 Hz when detection at 200 Hz ($2f_0$) is desired.

Our double junction devices are constructed in a manner similar to that already described in the literature.[1,3,4] Suitable devices have room temperature resistance values ranging from 0.2 to 2 Ω, and critical currents ranging from 10 μA to 1 mA at 4.2°K. For double junction currents greater than the critical current i_c, the voltage v is an oscillating function of the magnetic flux threading the area between the two Josephson junctions. The magnetic field results from the current I_H in the niobium superconducting wire which runs through the device. Figure 2(A) illustrates the voltage v across one such device plotted as a function of I_H. Most of our devices have several sets of oscillations superimposed on each other. However, the shorter period oscillations (~ 0.2 mA), which presumably arise from individual junctions separated by a larger area, tend to deteriorate with the cycling of the device temperature between 4.2 and 300°K. Changes in the critical current with respect to I_H are detected by superimposing on I_H a small ac modulating current $\Delta I_H \sin(2\pi f_0 t)$, where ΔI_H is much less than the period in I_H of the oscillations, and synchronously detecting the differential voltage change. The first derivative of the device voltage with respect to I_H is shown in Fig. 2(B). Detection of the signal at $2f_0$ yields the second derivative, which is shown in Fig. 2(C) as a function of I_H.

The potentiometer can be operated simply as a null detector if the time constant associated with the low temperature part of the circuit is not prohibitively long (>10 sec) and a wide range of sample measuring currents is desired. The device operating point is chosen by adjusting I_H such that either the slope of the first derivative or the second derivative is a maximum depending on whether the signal is detected at f_0 or $2f_0$. This operating point