**A SENSITIVE ALPHA AND BETA-RAY
CALORIMETER**

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A SENSITIVE ALPHA- AND BETA-RAY CALORIMETER*

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ABSTRACT

A sensitive calorimeter suitable for measuring the power output of small alpha and beta ray sources is described. The calorimeter is of the twin type and is capable of detecting power levels as low as 5×10^{-7} watts.

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FIGURE CAPTIONS

Figure 1 Top view of calorimeter with lids removed.

Figure 2 Cross section of calorimeter.

Figure 3 Jacket temperature control circuit.

Figure 4 Temperature null indication circuit.

INTRODUCTION

Previous work in radiation calorimetry at this laboratory has been with a total-absorption gamma-ray calorimeter⁽¹⁾. As part of our program to apply calorimetry to dosimetry, we have constructed a calorimeter of small mass for alpha and beta ray measurements. This permitted working out the details of jacket temperature control, temperature measurements, and also provided general experience in calorimeter techniques.

A twin-type calorimeter was chosen for several reasons; first, since the twin calorimeter requires only a differential temperature measurement, it allows us to use a thermopile. A thermopile may be very sensitive and still not have the problem of heat dissipation common to other temperature measuring systems. Second, the twin calorimeter is constructed symmetrically so that changes in its environment affect each cell identically. This tends to reduce the dependence on jacket stability permitting more sensitive temperature measurements than with equivalent jacket control in a single cell system. Third, when the calorimeter is in operation it is constantly being calibrated, which makes it very convenient for routine power measurements, half life measurements, etc.

DESCRIPTION OF CALORIMETER

A top view of the calorimeter with the lids and insulation removed is shown in Fig. 1. Figure 2 is a cross sectional view with the lids in place. The primary absorbing material in each cell is graphite. Sample cavities are 2.2 cm in diameter by 3 cm deep and have 0.5 cm thick walls. A 0.5 cm thick lid with a small step fits into the top of each cell. The

lids are removable to permit access to the cell cavities. The graphite absorbers are mounted in lucite sleeves, which serves primarily as structural mounting blocks for the thermopile junctions. Holes were drilled through the lucite and a thermocouple inserted in each hole and cemented in place. The ends of the thermocouples were then machined until they were below the surface of the lucite to prevent electrical contact with the graphite. A thin layer of silicone grease was used to improve the thermal conductivity between the thermopile and the absorber.

When the calorimeter was first operated, temperature fluctuations inside the calorimeter were about an order of magnitude more severe than the indicated variation in the isothermal shield temperature. This problem was eliminated with the installation of a heat baffle. The copper heat baffle, shown in Figures 1 and 2, is 0.3 cm thick and completely surrounds the cells. The top of the baffle is held in place with screws which permit removal for access to the cells. Expanded polyurethane is cast into the space between the baffle and the cells to serve as thermal insulation. A layer of styrofoam surrounds the baffle and insulates it from the isothermal shield.

The isothermal shield was constructed from 20 gauge copper. The entire outside surface of the shield is covered with a uniformly wound layer of cotton covered manganin wire which serves as a heating element. A lip on the shield lid provides good thermal contact with the body of the shield when the calorimeter is assembled. A 4.5 cm thick layer of styrofoam surrounds the isothermal shield and serves to isolate it from variations in room temperature.

FIGURE 1
Top View of Calorimeter with Lids Removed

FIGURE 2
Cross Section of Calorimeter

ISOTHERMAL JACKET CONTROL

Isothermal-shield temperature is controlled by a feedback system. A block diagram of this circuit is shown in Fig. 3. The temperature is sensed by two thermistors attached to the inside wall of the shield. The thermistors are electrically wired in parallel and form one leg of a Wheatstone bridge circuit. The bridge output signal is amplified and fed to a strip chart recorder which has a Honeywell Electr-o-volt three mode proportional control unit. Power for the heating element is provided by the proportional control unit. Chart records indicate that the isothermal shield can be controlled to $\pm 2 \times 10^{-5} \text{ }^{\circ}\text{C}$ over a period of several days.

READOUT CIRCUIT

Figure 4 presents the temperature readout circuit of the calorimeter. The thermopile connecting the two cells has 32 junctions of 26 gauge iron and 20 gauge constantan. The number of junctions was chosen to give optimum sensitivity when the thermal conductivity and electrical resistivity of the wires, the thermal conductivity of the styrofoam insulation and the input impedance of the galvanometer were considered. Thermopile sensitivity with the system is about $5 \times 10^{-6} \text{ }^{\circ}\text{C}$. The temperature coefficient of the galvanometer amplifier required placing the amplifier in a temperature controlled box in order to make use of the available sensitivity.

OPERATION

Measured time constant for the system is 30 minutes, which allows measurements to take place in about 4 hours. To operate the calorimeter, a sample is placed in one cell and a calibration coil in the other. The calorimeter is then closed. Electrical power is applied to the coil to keep the thermopile galvanometer nulled. The power required in the calibration coil to null the galvanometer, when the calorimeter is at equilibrium, is equal to the power produced by the sample being measured.

FIGURE 3
Jacket Temperature Control Circuit

FIGURE 4
Temperature Null Indication Circuit

REFERENCE

1. I. T. Myers, W. H. LeBlanc, and D. M. Fleming. "Precision Adiabatic Gamma-Ray Calorimetry Using Thermistor Thermometry," Rev. Sci. Instr. 32, p. 1013 (1961).

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