ARMOUR RESEARCH FOUNDATION
of
Illinois Institute of Technology
Technology Center
Chicago 16, Illinois

ARF 1192-3

(Quarterly Report No. 1)

A STUDY OF THE FEASIBILITY OF USING SCINTILLATING FIBERS FOR LOW ENERGY BETA COUNTING

Contract No. AT(11-1)-578
Project Agreement No. 10

to

U. S. Atomic Energy Commission
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois

Attn: Fred C. Mattmueller, Director
Research Contracts Division

(Covering the Period from June 15, 1961 to September 14, 1961)

January 5, 1962

A STUDY OF THE FEASIBILITY OF USING SCINTILLATING FIBERS FOR LOW ENERGY BETA COUNTING

I. INTRODUCTION

Numerous liquid scintillation counters and counting techniques are described in patent and periodical literature. There are a number of desirable advantages in liquid scintillation counters, i.e., high sensitivity, speed, and the possibility of easily doing dual tracer experiments. However, it is pointed out by papers written on the subject and others in the field that the major difficulty in liquid counting for many applications is the necessity for special sample preparation. This results from the necessity to dissolve or suspend the sample in a scintillating solution maintaining reasonable optical properties and without "quenching" the scintillator. Chemical manipulations as solutions to this problem are often time consuming and expensive. A detector system with the advantages of a liquid counter, but without the severe requirements on sample preparations, has been devised and is the basis of the present experimental investigation.

II. TECHNICAL DISCUSSION

In this study we are concerned with the sensitivity of the fiber scintillation counter. In order to determine this we must know what factors limit the smallest pulse which we can detect. The limitation on the counting of small pulses is imposed by the presence of background pulses arising in the scintillation counter system. We found that the most troublesome background is from the photomultiplier tube itself.

We have examined a number of photomultiplier tubes for low noise. The procedure was to seal the individual tube in a completely dark housing and allow each tube to set for twelve or more hours in this environment. The tubes were then operated for a plot of noise versus high voltage. A typical noise vs. high voltage plot for the tubes examined is shown in Fig. 1. All of the noise data obtained to date is with the P-M tubes operated at room temperature.

A high gain low noise pre-amplifier and amplifier suitable for this type counting were then selected. While coincidence instruments with pulse height analysis are generally considered to be the best equipment to use in this type of counting, we are using a single P-M tube for this preliminary investigation. While there are special hand made low noise photomultiplier tubes to be had on the market at premium cost, we felt that the common variety P-M tube readily available should be used in this test.

In order that 2π geometry be approached, fibers of small diameters are used around which the sample is dispersed. The diameters of the fibers being used are 0.5, 1.0, and 1.5 millimeters, respectively. The fibers are cut to 5.0 centimeter lengths and the ends polished to insure good optical coupling to the multiplier photo-tube interface.

Calculations of the void (sample) volume in a system of close packed cylinders show that a constant fraction of the volume can be obtained which is independent of the diameter of the cylinder. Consider a rectangle with side dimensions of W and d packed with cylinders of diameter D. The volume taken up by the cylinders (scintillators) for cubic packing is

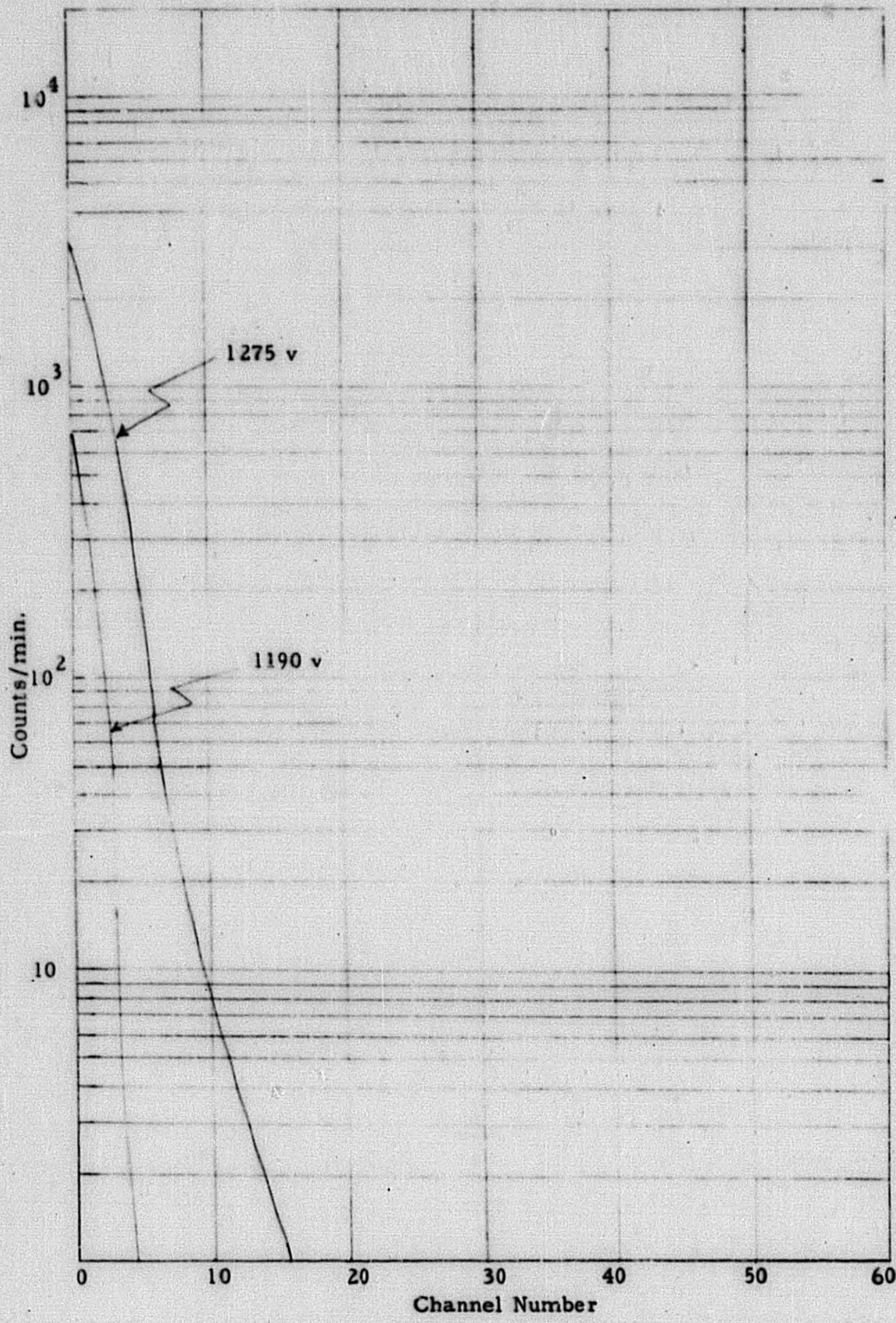

Fig. 1. TYPICAL NOISE SPECTRUM OF MULTIPLIER PHOTO-TUBES

(512 channel analyzer used)

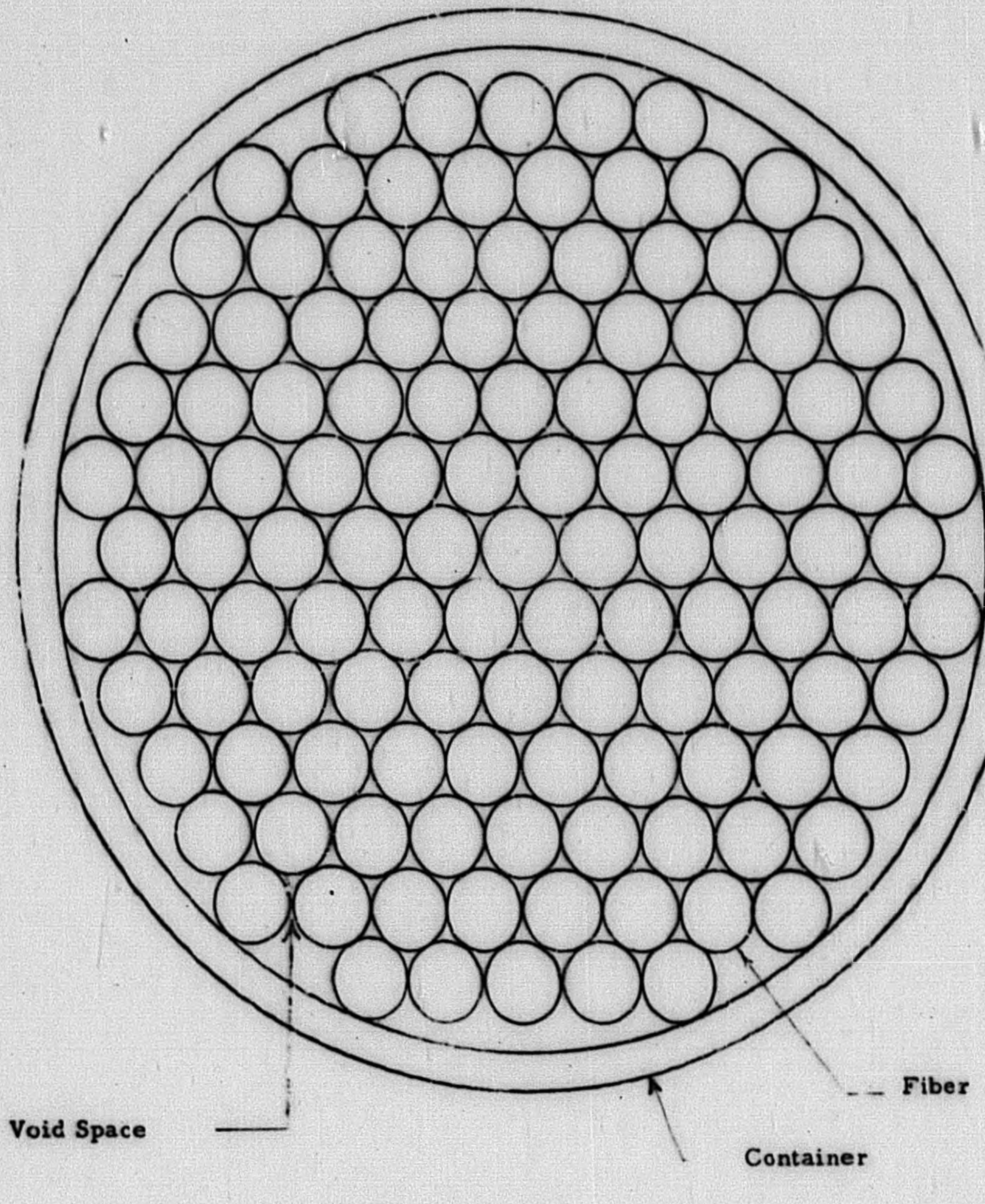

Fig. 2. FIBER BUNDLE END VIEW

$$V_1 = \frac{\pi D^2}{4} \quad \frac{W}{D} \quad \frac{d}{D} = \frac{\pi WdL}{4}$$

where L is the length of the system. The fractional volume remaining is given by

$$\frac{V_2}{V_t} = \frac{V_T - V_1}{V_t} = (WdL - \frac{\pi WdL}{4} / WdL)$$

Thus

$$\frac{V_2}{V_t} = 1 - \frac{\pi}{4} = 0.215$$

indicating that the sample volume is 21.5 percent of the total.

In practice, however, a hexagonal close packing is utilized which is the most natural array as shown in Fig. 2. The ideal sample volume realized from this array should be approximately 15 percent of the scintillator volume. However, the actual measured sample volumes of the fiber detector bundles two inches in length by one-half inch in diameter obtained for 0.5, 1.0, and 1.5 millimeter fibers were 11, 16, and 21 percent respectively.

Fabrication of a simple water jacket for P-M tube cooling to further reduce tube noise and increase sensitivity is in progress. With this improvement it is expected that reliable and accurate measurements of the efficiency can be made. Variables to be studied will include fiber diameter, fiber length, color of the counting solution and index of refraction of the counting solution.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology

C. Preston

C. Preston, Experimentalist
Nuclear and Radiation Physics Section

APPROVED:

C. A. Stone

C. A. Stone, Assistant Director
of Physics Research