SLAC-PUB-1283
(I)
August 1973

CONSTRUCTION AND PERFORMANCE OF A LARGE LIQUID SCINTILLATION COUNTER*

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Abstract

A liquid scintillation counter with an active volume 3.05 m x 0.20 m x 0.20 m was constructed with a simple, inexpensive, and rugged design. Some properties of this counter are reported.

(Submitted as a Letter to the Editor, Nucl. Instr. and Methods)

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*Work supported by the U. S. Atomic Energy Commission

Scintillation counters which are "thick", presenting more than 3 grams/cm^2 in the path of an incident particle, have several experimental applications. The most common has been the detection of neutrons, for which added thickness gives added conversion probability.[1-5] In detecting minimum ionizing particles the >6 MeV energy deposition in a thick scintillator can provide a handle for rejecting backgrounds of lower energy photons or neutrons. Mineral oil based liquid scintillator is often preferred to plastic scintillator in the construction of thick counters because its cost per gram is typically an order of magnitude smaller. For the detection of neutrons, the mineral oil based liquid offers the added advantage of nearly twice as many hydrogen atoms per gram. These advantages, however, are somewhat offset by the necessity of providing a container for the liquid. Some experimenters have constructed containers of lucite, which provides a good optical interface with the liquid, and whose outer surface then gives internal reflections for ligh transmission.[1,4] In this paper a counter with a different construction is described.

A schematic cross section of the counter is shown in Fig. 1. The container is a 4.27 m length of 20.3 cm $\times$ 20.3 cm $\times$ 0.5 cm thick structural steel tubing. The tube extends beyond the 3.05 m active length of the counter in order to support the phototube assemblies, and to provide an overall rigid, inpenetrable package.

The active region of the tube is lined on the inside with 0.13 mm thick Teflon FEP film, type C.[6] The etched surface of the film was cemented to the steel, and the smooth surface left free. Because the index of refraction of the Teflon (1.34) is lower than that of the liquid scintillator to be described later (1.49), total internal reflections occurred at the scintillator-Teflon interface for light within 25° of grazing incidence.

The ends of the active region of the tube were closed with 2.54 cm thick Plexiglass[7] windows. The seal betweenthe steel and the Plexiglass was made with Silastic 732 RTV.[8] Fill holes were located on one side of the tube in the center of the active region, and 0.31 m from each end. Brass bulkhead fittings with ~1 cm threaded openings were cemented into these holes, into which could be screwed either plugs or light-emitting diode fixtures. The active volume of the counter was filled with Pilot Standard Mineral Oil Scintillator.[9] In a period of over 1 year no deterioration in any of the seals, bonds or materials was observed.

Each end of this container was viewed by an Amperex 56 DVP phototube.[10] Because of the large area mis-match between the 4.2 cm diameter photocathode and the 19.3 cm square window, not all light leaving the end of the counter could be transmitted to the phototube. Consequently the transmission was tailored with conical light guides to optimize the transmission for "prompt" light traveling nearly parallel to the counter axis. The light guides were solid cones of polished Plexiglass[7] 30.5 cm high with end diameters of 4.2 cm and 19.3 cm. The cones were cemented to the phototubes, but not to the Plexiglass windows. Magnetic mu-metal shields were placed over the phototubes, and the entire phototube assemblies were attached to the inner wall of the steel tube with aluminum brackets.

The cost of the materials in this counter, exclusive of phototubes, was ~\$260.00. The labor costs are difficult to estimate. It should be noted, however, that the only operation requiring a machinist was the manufacture of the conical light guides.

Several of the properties of this counter were measured in simple tests using small defining counters to give a "beam" of cosmic ray muons. The pulse height from a phototube was found to decrease only by a factor of 2.0 ± 0.2 as the beam moved from the near end of the counter to the far end. This implies an attenuation length for the counter system of $\lambda = 4.4$ m. When the average of the arrival times of the pulses from the two phototubes was used to compute the position-compensated arrival time ($\bar{T}$) of the cosmic ray, the r.m.s. timing resolution was found to be $\Delta \bar{T} = 0.6 \pm 0.2$ nsec. When the difference between the arrival times of the pulses from the two phototubes was used to determine the position (S) of the cosmic ray, the r.m.s. position resolution was found to be $\Delta S = 10. \pm 3$ cm. The propagation speed of light along the counter relative to c was measured to be $\beta = 0.55 \pm 0.05$.

The resolutions $\Delta \bar{T}$ and ΔS are assumed to be dominated by photon statistics, and hence inversely proportional to the square root of the energy deposited. This hypothesis was confirmed by comparing ΔS measured with cosmic rays (40 MeV deposited) to the large ΔS measured with a CO^{60} source ($\sim$1 MeV deposited).

To place the cost and performance of this counter in perspective it is interesting to compare it to a counter of similar area, but only 2.5 cm thick, made of Pilot Y scintillator.[9] The properties of such a counter[11] are listed beside those of this counter in Table I. In each case the counter has a 56 DVP phototube on each end, but the costs of the phototubes are not included in the prices. Similar tests with cosmic ray muons were performed on each. The counters are similar in all respects except that the liquid counter described here is $\sim 7\times$ thicker in grams. The plastic counter is slightly more expensive and gives slightly better resolution.

Another interesting comparison is between the counters' abilities to reject low energy backgrounds when each is biased to detect minimum-ionizing particles. On different occasions each of these counters has been operated under effectively the same conditions in the experimental environment of the electron-positron storage ring SPEAR. This environment has a low-energy-divergent sea of photons and electrons typical of that in any electron accelerator. Here the counting rate in the thick liquid counter was 4-16 times lower than that in the thin plastic counter. The range indicates the uncertainty in relative normalization. Clearly the higher energy requirement possible with the thicker counter makes it quieter.

I would like to thank Ron Seefred and Joe Strong for assistance in building and testing this scintillation counter.

TABLE I

		Counter	
		Liquid	Plastic
Dimensions			
length	(m)	3.05	2.54
width	(cm)	20	20
thickness	(cm)	20	2.5
thickness	(gram/cm^2)	19	2.6
Materials cost			
less phototubes		\$260	\$350
Properties			
λ		$4.4 \pm .6$	$3.8 \pm .6$
$\Delta \bar{T}$ (nsec)		0.6 ± 0.2	0.38 ± 0.03
ΔS (cm)		10 ± 3	6.0 ± 0.5
β		0.55 ± 0.05	0.52 ± 0.01

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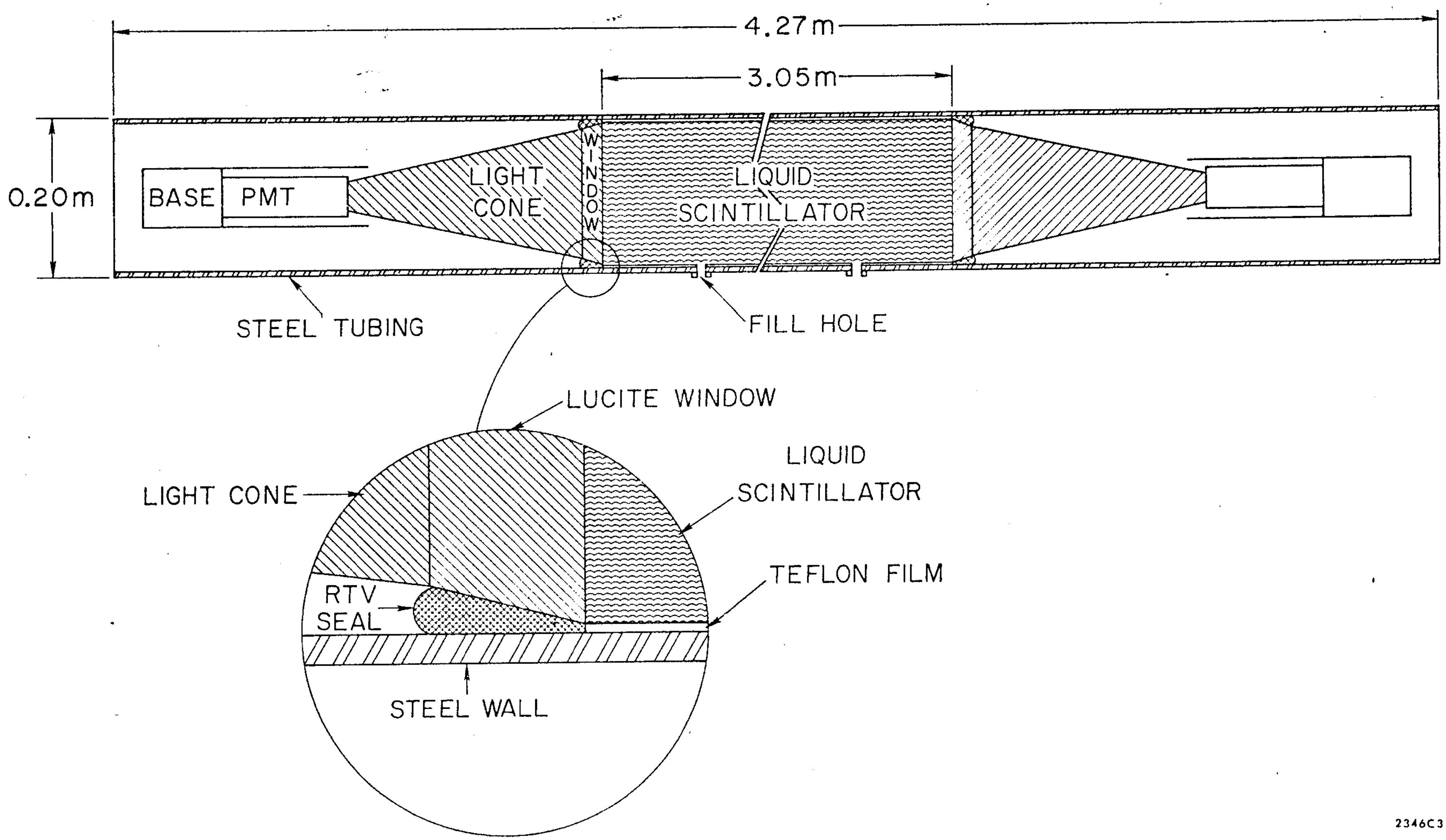

FIG. 1

A schematic cross section of the counter.