THE EFFICIENCY OF A BIG AREA LIQUID SCINTILLATION COUNTER

by

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Abstract : The efficiency of a big area liquid scintillation counter was investigated. It has a constant efficiency $\sim$ 99% at the middle region and it varies at the other parts for the same discriminator voltage. The efficiency of any half was found to be a mirror image for the other half. A new type of a big area liqued scintillation counter was designed and constructed which has constant efficiency over all the area.

1. *INTRODUCTION*

The efficiencies of the individual counters connected in coincidence are almost independent and the efficiency of the coincidence arrangement is given by the product of the efficiencies of coincidence counter trays. If the multiplication of the coincidence arrangement is great, the error may be significent. On the other band the accuracy of any cosmic ray measurement depend on two parameters. The statistical fluctucations of the events and the fluctuations of the measured values due to either the variations of the efficiencies of the detectors or due to the defects of the electronics.

In this connection it seems of interest to study the efficiency of a big area liquid scientillation counter and to use it as a tool for accurate Cosmic-Ray measurement.

2. *EXPERIMENTAL ARRANGEMENT*

The general set up of the arrangement for measuring the efficiency of the liquid scintillation counter is shown in *Fig. (1)*.

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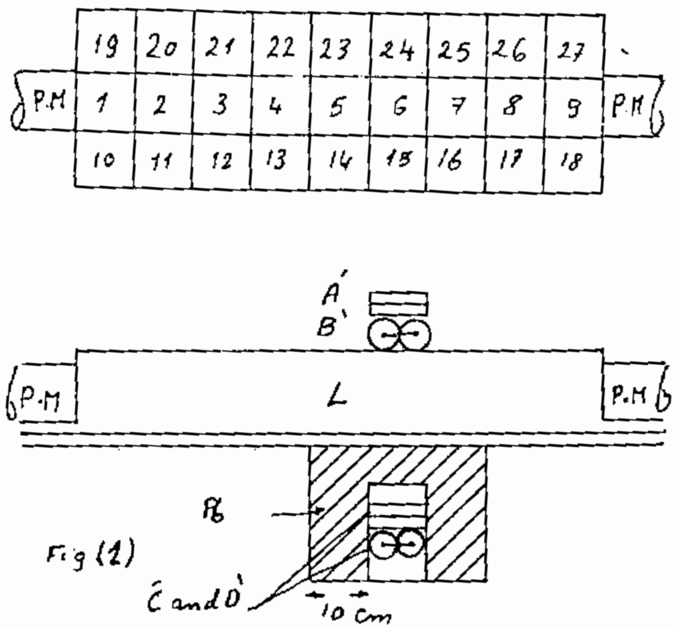

Fig. (1)

The container of the liquid scintillation counter (whose area 30×90 cm^2 and depth 10 cm.) was filled with a liquid scintillator (solution of para-terphenyl in pure xylene, 2 gm/liter). It had been coated by MgO from inside which acts as light reflector. Two RCA 6342 photomultipliers were sealed at the two narrow ends by a 5 mm thickness glass light pipe.

The efficiency of 40 self-quenching G.M. counter (4 cm ⌀ and 10 cm length) was measured by the method proposed by Janossy et. al (1, 2) as in *Fig. (2)* The efficiency of 29 G.M. tube out of 40 was found to be more than 99.9%. Eight of the G.M. tubes were chosen to be used whose efficiencies ranges between 99.94% to 99.96%. The G.M. counters were arranged into two trays each consists of 2 pairs crossing each other perpendicularly and in coincidence, giving an effective area of $\simeq$ 100 cm^2. The Block diagram of the electronics is given in *Fig (3)*

3. *RESULTS*

3.1 *Measurement of the efficiency of G.M. tubes*

In *Fig. (2)* The counters (A, B, C) are connected in coincidence. Z is

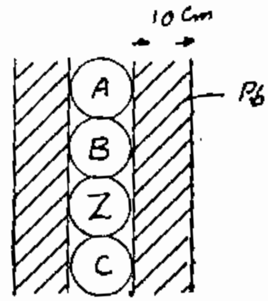

Fig. (2)

the counter whose efficiency wanted to be measured is in anticoincidence with the others. The number of anticoincidence (A, B, C, -Z) shows the number of events which the counter Z failed to detect.

$$\text{its efficiency} = 1 - \frac{(A,\ B,\ C,\ -Z)}{(A,\ B,\ C)}$$

Fig. (4) shows a sample of two G.M. tubes out of the eight used, via the overvoltages which is in good agreement with equations (i) and (ii) «Appendix»

3.2 *Measurement of the efficiency of the liquid scintillation counter.*

The upper surface of loquid scintillation counter was divided into 27 equal parts (each of area $\gtrsim$ 100 cm²). With the arrangement represented in *Fig. (1) and (2)* the efficiency of each part was measured for different discrimenation voltage using the following relation

$$L = 1 - \frac{(A',\ B',\ C',\ D',\ -L)}{(A',\ B',\ C',\ D')}$$

where each primed letter represents two G.M. tubes in parallel. *Fig. (5)* shows the efficiency of different zones on the liquid scintillation counter via the discriminator voltage. *Fig. (6)* gives the efficiency of the whole liquid scintillation counter via position for a fixed discriminator voltage, from which it is clear that the efficiency of one half is a mirror image for the second half.

It is clear from *Fig. 6* that the detection efficiency is constant through out the middle one third of the scintillation detector, while in both outer thirds the efficiency increases with the decrease of the events position

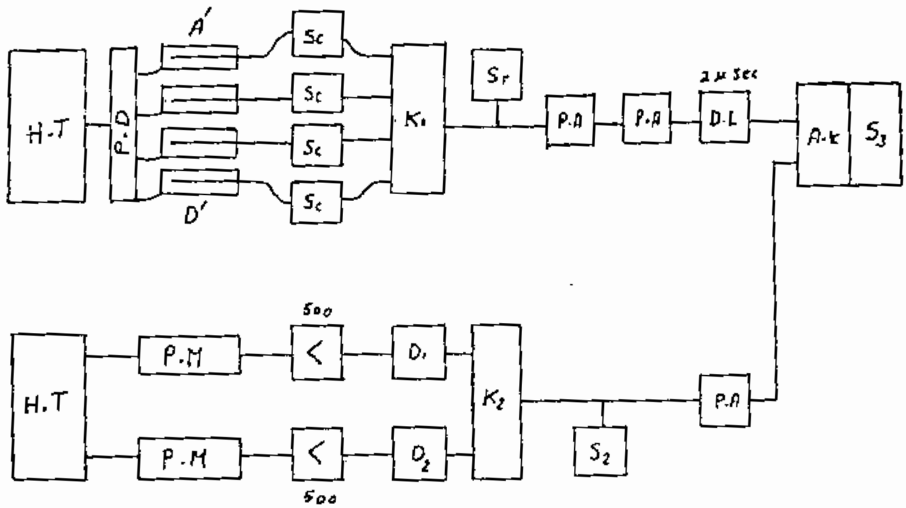
A'
Sc
Sc
Sc
Sc
D'
H.T
P.D
K1
Sr
P.A
P.A
2 μ sec
D.L
A.K
S3
500
H.T
P.M
P.M
D1
D2
500
K2
S2
P.A

Fig. (3)

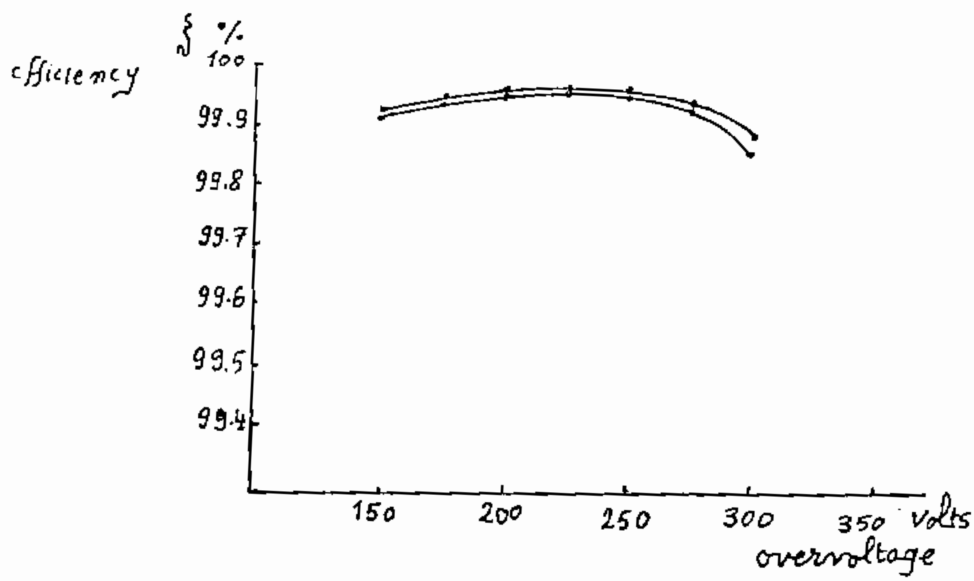
efficiency
ξ %
100
99.9
99.8
99.7
99.6
99.5
99.4
150
200
250
300
350 volts
overvoltage

Fig. (4)

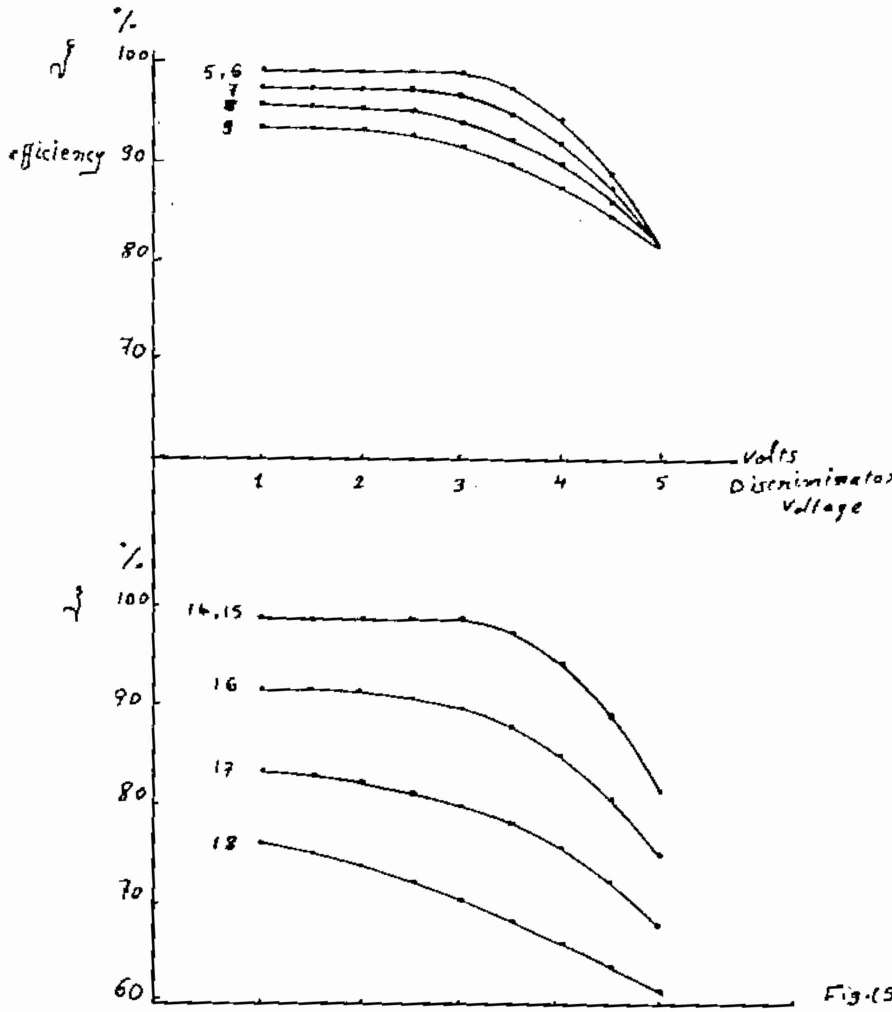
%
100
5, 6
7
[illegible]
9
efficiency 90
80
70
volts
1
2
3
4
5
Discriminator Voltage
%
100
14, 15
16
90
17
80
18
70
60

Fig.(5)

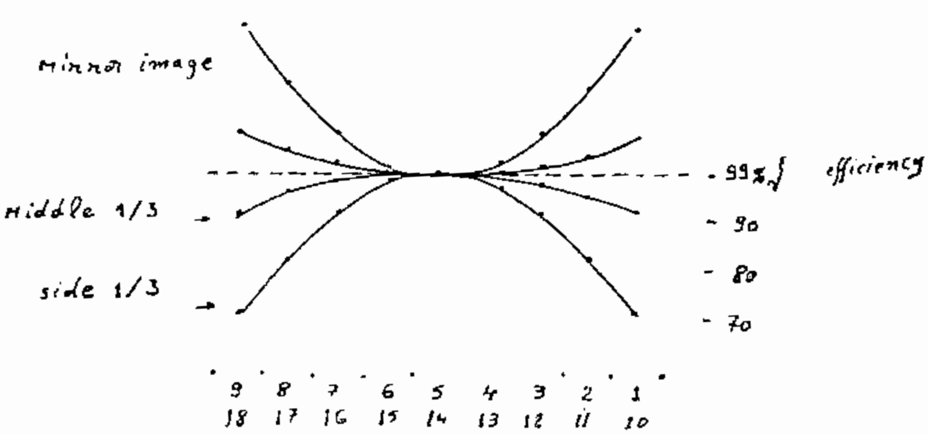
mirror image
Middle 1/3
side 1/3
99%
efficiency
90
80
70
9 8 7 6 5 4 3 2 1
18 17 16 15 14 13 12 11 10

Fig. (6)

from the center of the L.S.C. The latter deffect returns to the variation in the amount of light received by each P.M.T. from some cosmic ray events. This is due to : firstly, the difference in the solid angles subtended by the two photomultipliers and the event ; secondly, the difference in the amount of light absorbed in the liquid before reaching each P.M.T. as a result of the pronounced difference in the liquid thickness traversed.

Nevertheless, the geometry of this L.S.D. has shown that P.M.T. will give always the same out put pulse amplitude for all monoenergetic cosmic ray events detected at a distance $\leq$ 60 cm.

3.3 *Modified Liquid Sointillation Counter.*

From the results represented in 3.2 a modified L.S.C. was designed and constructed which has a uniform cosmic rays detection efficiency through out its area for each discrimination voltage. *Fig. (7)* gives its geometrical

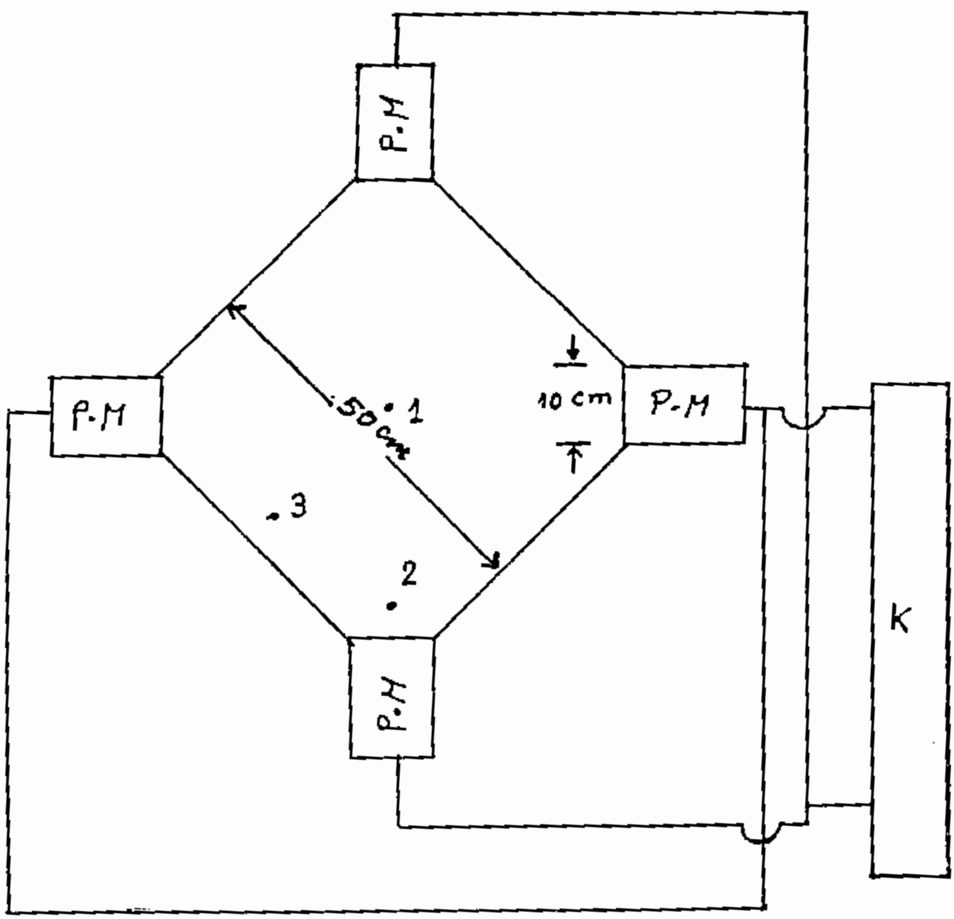

Fig. (7)

form and dimensions. The pulses arising from each 2 diagonaled P.M.T. are summed together and supplied to the coincidence circuit. The efficiency of the different zones of the counter had been determined as in 3.2 and was found the same over all the counter area. Samples of the results are given for four different positions.

The satisfactory results given by the modified L.S.C. show that it is a good tool for cosmic rays measurement.

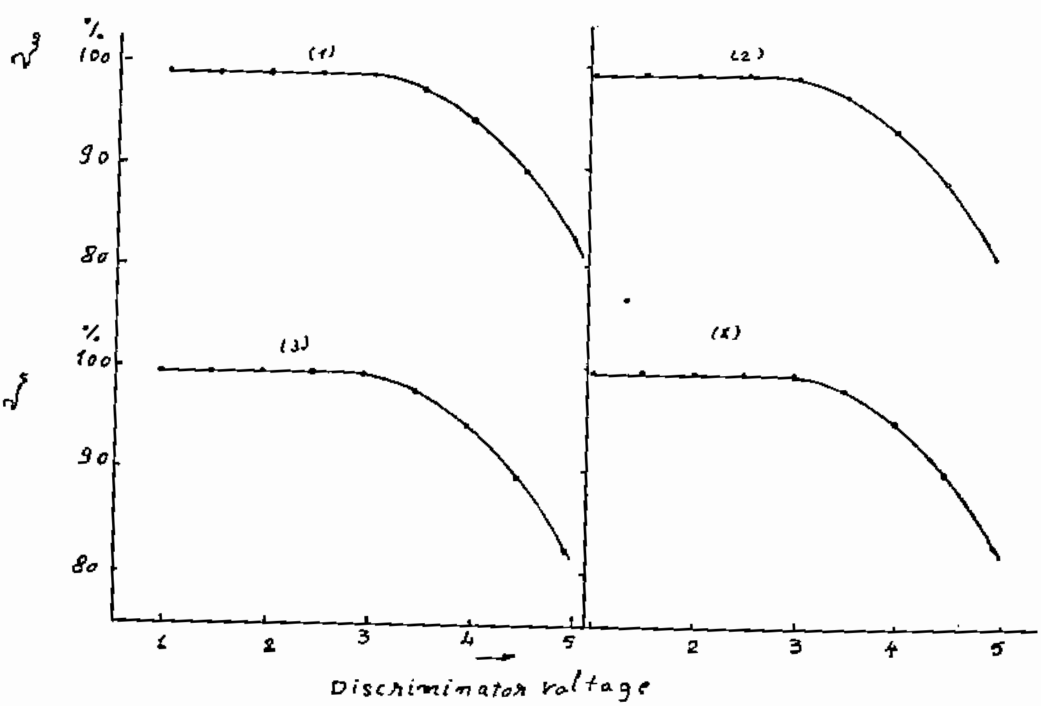

Fig. (8)

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APPENDIX

If a particle could not pass through the counter during its dead time, the probability that the particle will be detected by the counter is

$$P = e^{-N\tau}$$

since $N\tau$ is always $\ll 1$

$$\therefore \; P \simeq 1 - N\tau = \xi \quad \text{.............................. (i)}$$

where N is the rate of discharge for the counter, τ is its dead time and ξ is the efficiency of the counter. On the other hand for a particle traversing the very edge of a cylindrical counter, the efficiency is given by

$$\xi = 1 - e^{-2\,\rho\, J\,(r^2 - x^2)^{1/2}} \quad \text{(Neglecting } \tau \text{)}$$

where ρ is the density of the gas in the counter, J is the primary specific ionization and $2\,(r^2 - x^2)^{1/2}$ is the path length of the particle in the counter.

The effective efficiency of a counter is given by

$$\xi_{eff} \geqq 1 - \frac{1}{r}\int_0^r e^{-2\,\rho\, J\,(r^2 - x^2)^{1/2}}\, dx \quad \text{.............................. (ii)}$$

Haiman (3) equation (ii) was solved by numerical method which gives $\approx 99.9\%$

Also from equation (i) if we consider $N = 20$ particle/sec, τ in the average $\sim 10^{-5}$ sec

$$\xi \simeq 99.98\%$$

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