CHAPTER III

THE APPARATUS AND ITS CHARACTERISTICS

3.1 The Apparatus.

The three-fold coincidence was connected as shown in the following diagram (Fig.7).

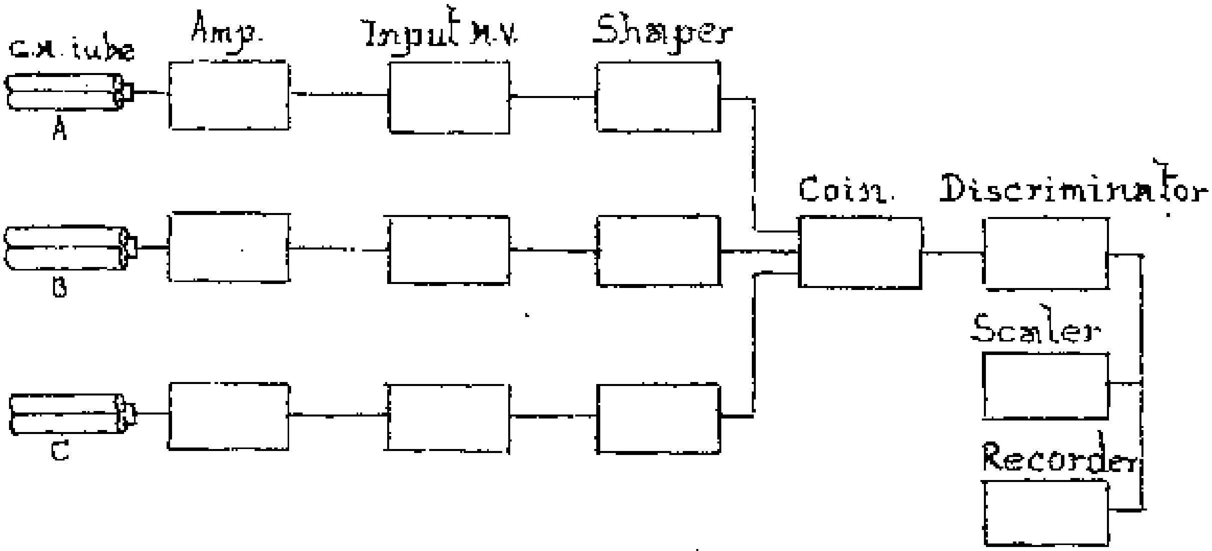

Fig.7 Block Diagram of the Apparatus.

Each channel consisted of G.M. tubes, amplifier, input multivibrator and shaper. A negative signal from the G.M. tube was amplified by the amplifier circuit. The pulse width and height then were controlled by the input multivibrator and shaper circuit. Three identical channels produce the same shape of the pulses at the output of the shaper circuits. The time lag of the pulse is the same for all three channels. The coincidence circuit will be operated only when three pulses from the shapers are within the limit of the resolving time. Before the pulse from the output of coincidence gets into the scaler circuit, the pulse must pass through a discriminator, which will cut out the small undesirable spurious pulses from the coincidence circuit. Then the scaler and milliameter recorder will show the number of coincidence pulses from the G.M. tubes. The detail of each circuit used is described as follows:

(1) Geiger Müller Tubes.

Six tubes were used in three pairs one above each other to form two trains of counter telescope as shown in Fig. 8. This telescope was arranged vertically, and its plane was in the direction of the magnetic meridian. These tubes are of type G.53, 20th Century Electronics Ltd., The expected working voltage is 1600-1800 volts, but the plateau as found was between 1725 to 1975 volts, then the operating voltage was set at 1775 or 1800 volts. The dead time of these tubes is 100 microseconds. The count rate of each channel is about 2000 counts per minute. Thus the counting loss according to the dead time of G.M. tubes can be neglected. The signal from the tubes is about 100-250 millivolts. The brass wall is used as cathode. The gas filling is argon and ethyl formate. The distance between the upper and lower pair can be set at 50, 80, or 105 centimetres.

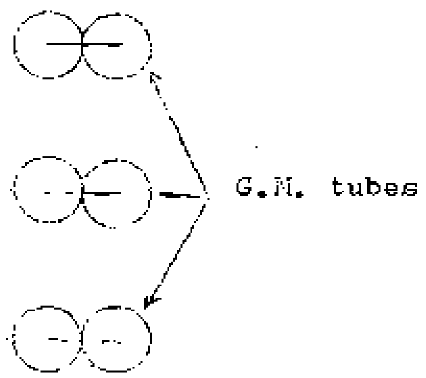

Fig.8 G.M. Tubes Arrangement.

(2) Amplifier.

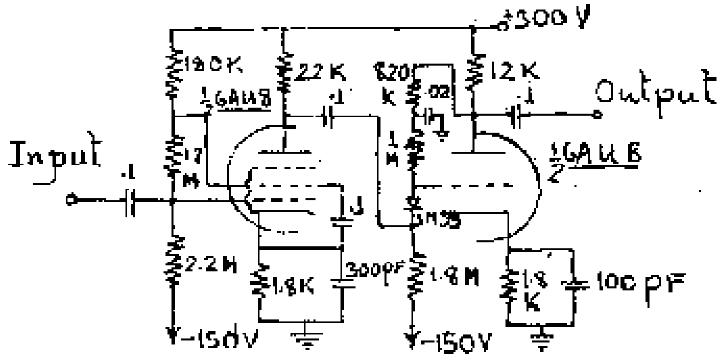

Fig. 9 Amplifier.

The twin vacuum tube is used as two stages R-C coupled amplifier. The total gain of this amplifier circuit is about 15, then the output signal from the G.M. tube after passing this circuit is between -1.5 and -4.5 volts.

(3) Input Multivibrator.

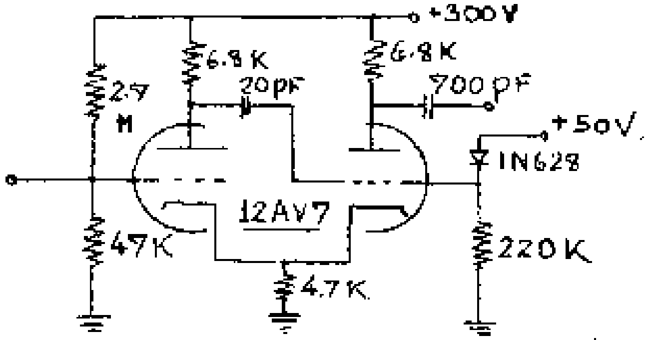

Fig. 10 Input Multivibrator.

The two tubes of this circuit was biased to be conducting at the stable state. The height of the input pulses, which can trigger this circuit, must be greater than 1 volt. The output of this part is about -60 volts. The pulse width can be controlled by the capacitor 20 picofarads, since all other resistors are fixed, the pulse width for this capacitor is 10 microseconds. The sensitivity of this circuit is so high that it can be used with the scintillation counters, or the count rate up to 10^5 counts per minute.

(4) Shaper

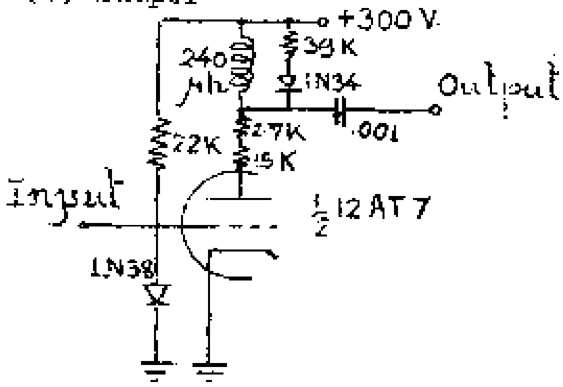

Fig. 11 Shaper

The pulse height from the input multivibrator is controlled by this circuit. The height of the pulse depends on the resistor 15 kiloohms and 2.7 kiloohms. The input, which can produce the good shape output, must be greater than 15 volts. The choke coil 240 microhenries, resistor 3.9 kiloohms and diode 1N34 are used for adjusting the edge of the pulse of the square wave output. In the circuit as shown in Fig. 11, the output is square wave with the height of 15 volts. The output height can be changed as desired by changing the load resistance.

(5) Coincidence Circuit.

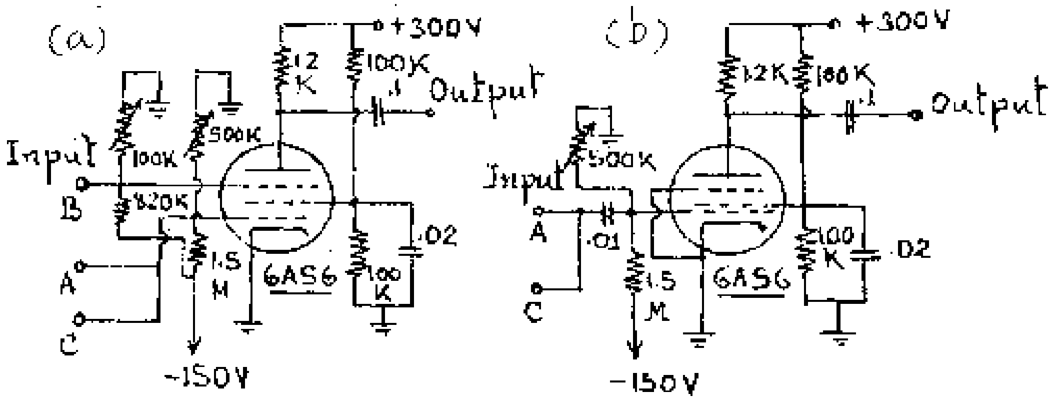

Fig. 12 Coincidence Circuit.

The tube 6AS6 was used as coincidence or gating circuit. The characteristic of this tube is such that the current will be 3 to 5 milliamperes, if the plate and screen voltage is 170 and 150 volts respectively, at the same time suppressor grid voltage and the control grid voltage is -3 or 0 volts and -2 volts respectively. The control grid and suppressor grid can be used as individual control elements. It is known that the output of the shaper is about 15 volts[1], and the combination of two channels from upper and lower G.M. tubes, A and C, is about 24 volts[1]. Then the suppressor grid was set at -12 volts and the control grid at -20 volts[2], which produce resolving time of about 10 microseconds. (The detail of resolving time measurement will be discussed in Section 3.2.1). The combination of the channel A and C are also fed into another two-fold coincidence as shown in Fig. 12b. The control grid is also biased at -20 volts. The advantage of this

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[1]Measured by Tektronix oscilloscope, type 531.

[2]Measured by V.O.M. Simpson model 260.

circuit is used for checking the stability of the coincidence, which may be caused by the tube itself or the change in value of biased resistors. This can be seen by comparing the coincidence count rate from double and triple coincidence. Every triple coincidence count must occur at the same time with the double coincidence, but usually double coincidence count rate is greater than triple coincidence count rate. Another advantage is that, it will be easier in the case of the determination of the active volume and efficiency. It is unnecessary to correct the effect of the variation of cosmic rays, since the double and triple coincidence are measured at the same time interval.

(6) Scaler and Recorder.

The Nuclear Chicago model 161A, and Texas Instruments Incorporated model PRR 1M. were used as scaler and recorder for the triple coincidence. Another Nuclear Chicago model 161A was used as scaler for double coincidence.

(7) High and Low Voltage Power Supplies.

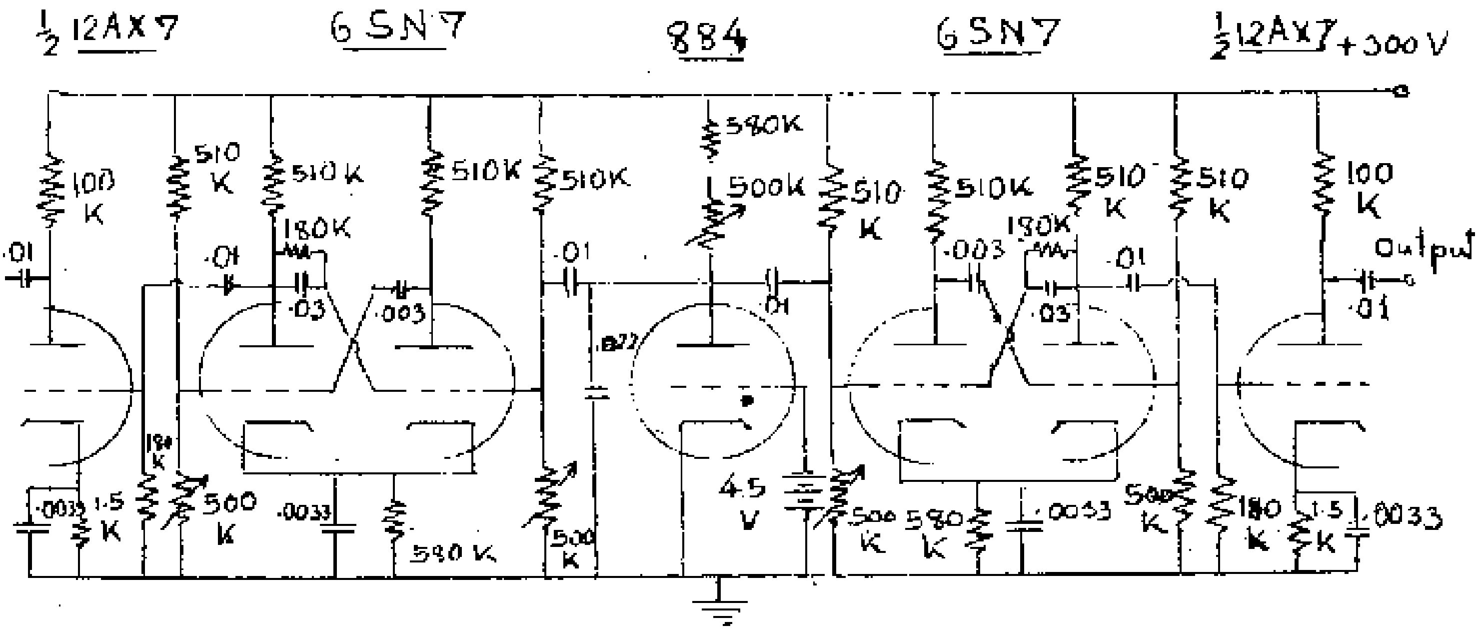
Two Nuclear Chicago model 161A, and one Nuclear Chicago model 1620 ce were used as high voltage power supplies. The regulated power supply +300 and -150 volts was used as the low voltage power supply. The A.C. lines for every part was stabilized by a voltage stabilizer, Craft type 1K022 No 15636.

3.2 Adjustments and Measurements of the Characteristics of the System.

3.2.1 Adjustment of Resolving Time of Coincidence.

The resolving time of the coincidence depends on the input pulse width and the bias voltage. In the case of the counter telescope, the resolving time should not be less than 5 microseconds. If it is too small the counting will be accidental count, since the particle should have a time for traveling from the upper to the lower detector.

The two pulse oscillator was constructed as shown in the circuit diagram in Fig. 13. The sawtooth wave form from the thyratron relaxation circuit was fed to two univibration circuits. The output from the univibrator is as shown in Fig. 13b, the positive pulse can be shifted by the change of the pulse width of the negative pulse, which is controlled by the biased resistor of the univibrator. The positive pulse then was fed to a high negative biased amplifier, which will operate only for positive pulse, then the negative pulse will be formed at the output of this tube. Two identical amplifiers were used for two univibrators. Then these two pulses from the amplifiers can be used for measuring the resolving time of the coincidence directly.



(a)

Fig. 13a Two-Pulse Oscillator

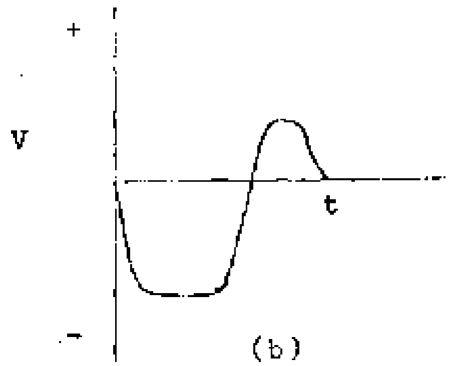


Fig. 13b Two-Pulse Oscillator.

The two outputs were fed into the amplifiers of the coincidence circuit. The output of two shapers were separated to connect to the inputs of the double beams oscilloscope.[1] The oscillator was adjusted until the time lag of these two pulses was 10 microseconds. The pulse width at the output of the shaper was also adjusted to be 10 microseconds. Then the bias voltage of coincidence was adjusted until the output pulses from the coincidence could pass through the discriminator.[2] The same method was used for another double coincidence at the same time. In the case of triple coincidence at first the two inputs were at the control grid and suppressor grid was connected to ground. It was found that for double coincidence the control grid was -20 volts, and for triple coincidence the suppressor grid was at -15 volts, the control grid at -20 volts.

3.2.2. <u>Determination of the Accidental Counts.</u>

The accidental count statistics was derived by

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[1]Cossor oscilloscope was used in this adjustment.

[2]Tektronix oscilloscppe was used in this measurement.

Schiff (29), and improved and tested by Eckart and Shonka (30). In these analysis, it was assumed that the accidental counts may be produced by,

a) distinct particles in each counter,
b) single particle in some of the counters,
c) any combination of single particle and true partial coincidences.[1]

In the case of the cosmic ray telescope the expected accidental counting rates for two, three counter coincidences may be calculated from (29)

$$A_{12} = 2\tau N_1 N_2 ,$$
$$A_{123} = 2\tau (N_1 N_{23} + N_2 N_{13} + N_3 N_{12}),$$

where $A_{12.....n}$ is the accidental count for those n counters in coincidence,

N_i is the count rate of individual counter,

$N_{12.....i}$ is the coincidence rate between all those counters from 1 to i

τ is the resolving time of coincidence.

The output from each shaper was connected to the scaler and the count rate of these channels was recorded. Let

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[1] True partial coincidence is defined as a true coincidence produced by one particle traversing more than one but not all the counters.

these count rates be N_A, N_B and N_C. When the combination of two channels A and B, B and C, A and C, was fed to the double coincidence circuit, let these count rates be N_{AB}, N_{BC} and N_{AC}, respectively. It was found that

$$N_A = 1800 \quad \text{cpm},$$
$$N_B = 1500 \quad \text{cpm},$$
$$N_C = 1700 \quad \text{cpm},$$
$$N_{AB} = 10.5 \quad \text{cpm},$$
$$N_{BC} = 13.0 \quad \text{cpm},$$
$$N_{AC} = 4.1 \quad \text{cpm},$$
$$\tau = 10 \quad \mu\text{-sec.},$$

then $A_{AC} = 1.02$ cpm,

$A_{ABC} = 0.02$ cpm.

3.2.3. Determination of the Efficiency of Coincidence.

For three counters placed in a line in a vertical plane, a triple coincidence may represent the passage of a single ray through the train of counters or the simultaneous excitation of the three counters by several rays from a shower. Likewise a double coincidence between the two extreme counters may be caused by a single ray passing through them or it may be caused by shower particles passing through the extreme counters. If the observed triple and double coincidence rates are corrected for accidental counts and later corrected for those showers, the resulting rates will represent a single ray through all three counters. These two rates should be equal provided that the central counter produce a ray passes through it. Since the counters are not perfectly efficient in producing pulses the corrected rates are not equal and the efficiency is given by the ratio of the triple rate N_t and double rate N_d, as shown by the experiment of Street and Woodward(28). The efficiency N_t/N_d, if all the double rate were substracted by a constant 0.052 count per minute, arising from the distribution due to showers, will be true efficiency and independent of the space between the counters.

The G.M. tubes were set as in Fig. 8, the triple and double coincidence count rates were recorded, and then these count rates were corrected for accidental counts and showers. The results were as follows:

N_t = 16.533 cpm,

N_d = 17.566 cpm., after the accidental counts were corrected. Then the efficiency can be calculated to be

$$E = \frac{16.533}{17.566-0.052} = 0.945.$$

During every measurement the double and triple coincidence was detected all the times, and it was found that the efficiency did not change very much.

3.2.4. Determination of Active Volume of counters.

The active volume can be determined in the same manner as Street and Woodward's experiment(28). The three counters are arranged as shown in Fig.14a, and the ratio of the triple to double coincidence were calculated for various displacement of the central counter. By assuming that the counters behave as uniformly sensitive rectangular areas as shown in Fig. 14c, the approximate expression for the ratio as a function of the displacement and the diameter D is as follows;

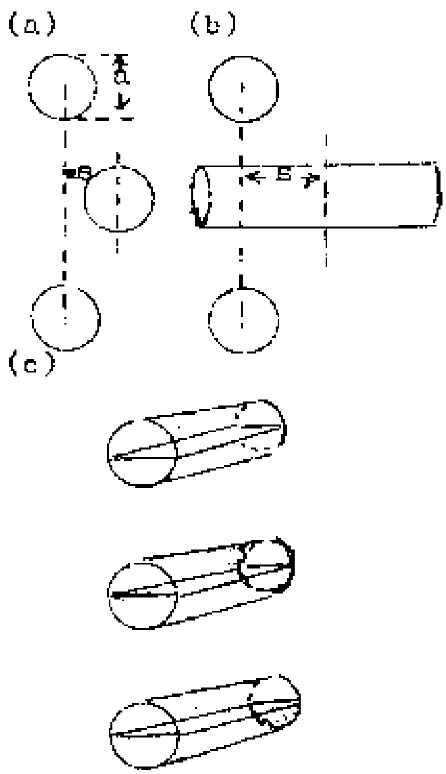


Fig. 14 Determination of Active Volume.

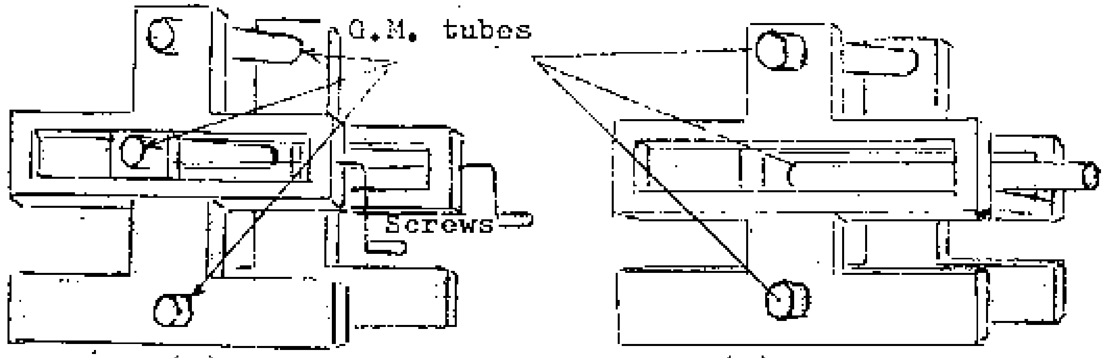
$$N_t/N_d = K[1-2(s/D)^2] \quad \text{for } s < D/2,$$

$$N_t/N_d = K(1-s/D)^2 \quad \text{for } s > D/2.$$

The values of K and D are determined from the maximum and half values of N_t/N_d, and substracted the double rate by 0.052 count per minute from the experimental observation due to showers. Then the active diameter D can he found.

The active length L can be measured in the same way as that of diameter by turning the central counter through 90^o as shown in Fig.14b.

The wooden frame was constructed as shown in Fig. 15. The central counter can be moved by adjusting the screws. The single G.M. tube triple coincidence was used. The accidental count was found again for the single tube, and found that



(a) (b)

Fig. 15 The Arrangement of the Active Volume Determination.

$$N_{AC} = 0.18 \quad \text{cpm.},$$

$$N_{ABC} = 0.005 \quad \text{cpm.}.$$

The triple and double coincidences were recorded at the same time and at various displacements of the central counter. The arrangement as shown in Fig. 15a was used for determining the active diameter and that as shown in Fig. 15b was used for the active length measurement.

The triple and double coincidence count rates were then corrected for the accidental counts and showers. The result of the determination of the active diameter is as shown in Table 3-1;

Table 3-1 The active diameter determination.

s distance in cm.	N_d doub. coin. rate.	N_t tri. coin. rate.	N_t/N_d
-3	6.24±0.34	0.63±0.01	0.101±0.016
-2.5	6.32±0.22	1.56±0.01	0.238±0.016
-2.25	6.10±0.19	1.84±0.01	0.312±0.019
-2	7.00±0.48	2.06±0.26	0.330±0.042
-1.75	5.88±0.29	2.39±0.19	0.422±0.038
-1.5	7.40±0.32	3.95±0.24	0.549±0.037
-1	5.33±0.28	3.23±0.22	0.630±0.049
0	6.07±0.31	5.43±0.29	0.895±0.063
1	6.07±0.31	4.39±0.26	0.725±0.054
1.5	6.60±0.32	2.77±0.20	0.420±0.037
1.75	5.90±0.32	2.62±0.20	0.445±0.038
2	5.90±0.34	2.19±0.18	0.471±0.037
2.25	7.16±0.33	1.82±0.16	0.252±0.043
2.5	6.58±0.32	1.55±0.15	0.237±0.025
3	5.90±0.30	0.85±0.11	0.144±0.015

Table 3-2 The active length determination.

s distance in cm.	N_d doub. coin. rate.	N_t tri. coin. rate.	N_t/N_d
-29.75	6.59±0.16	0.21±0.03	0.031±0.006
-27.25	4.36±0.17	0.21±0.05	0.069±0.006
-24.75	4.67±0.20	0.62±0.07	0.133±0.006
-22.25	6.60±0.39	0.89±0.10	0.135±0.005
-17.25	6.68±0.32	0.99±0.12	0.150±0.006
0	6.74±0.33	1.02±0.13	0.152±0.005
17.25	6.42±0.31	0.97±0.10	0.151±0.006
22.25	6.65±0.32	0.79±0.11	0.118±0.006
24.75	6.21±0.30	0.49±0.08	0.079±0.006
27.25	6.80±0.33	0.19±0.06	0.027±0.003

The graph of the ratio of N_t and N_d versus the displacements was plotted as shown in Fig.16.

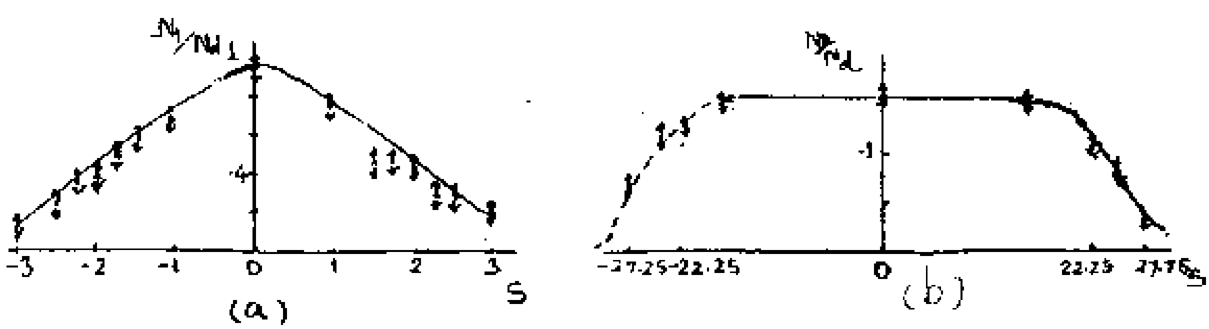


Fig.16 The graph of N_t/N_d versus s.

Then the active diameter D can be found by calculation from the graph in Fig.16a. In the case of the active length, L should be calculated from both sides of the graph in Fig.16b, because of the asymmetry of the curve of the two sides. The coordinate also was shifted to fit the expression of the active diameter. Then the length from both sides of the graph were calculated, the active length being the average of the length from both sides. It was found that,

(1) the diameter D is 3.8 centimetres,

(2) the active length L from the left hand side of the graph is 48.8 centimetres,

(3) the active length L from the right hand side of the graph is 54.7 centimetres,

thus the effective active length is 51.25 centimetres.