II

EXPERIMENTAL TECHNIQUES

2.1 Recording of meson component

2.11 Introduction

In 1950 a comprehensive programme of cosmic ray variation was begun by cosmic ray research group of Physical Research Laboratory, Ahmedabad. One of the chief objectives, on development side of the programme, was the establishment of sea level and mountain level cosmic ray recording stations along the 75°E meridian section and spread out over a wide range of latitudes ranging from geomagnetic equator, in South India, to as high a latitude as could be reached in the North India. In pursuance of this objective cosmic ray recording stations were first set up at Ahmedabad (\(\lambda = +14^\circ\), \(f = 144^\circ\), \(h = \text{sea level}\)), Kodaikanal (\(\lambda = +1^\circ\), \(\varphi = 147^\circ\), \(h = 2343\text{m}\)) and Trivandrum (\(\lambda = -1^\circ\), \(f = 146^\circ\), \(h = \text{sea level}\)). In the middle of 1955 the author was entrusted with the task of setting up a high altitude cosmic ray recording station at Gulmarg (\(\lambda = 25^\circ\), \(f = 147^\circ\), \(h = 2740\text{m}\)) in the Himalayas. To start with, it was decided to concentrate only on devising satisfactory means of

\* \(\lambda, f, h\) are respectively the geomagnetic latitude, geomagnetic longitude and height above sea level of the station.
recording hard component of cosmic rays by counter telescopes. To decide the geometry of counter telescopes account was taken of the work of Sekido et al (1950) who showed that the amplitude of diurnal and semidiurnal components of solar daily variation increases as the angle in the E-W plane is narrowed and of Sarabhai et al (1955) who showed that it was enough to have a semiangle of 5° in the E-W plane because any further diminution of the angle of opening in E-W plane did not significantly increase the amplitude of solar daily variation but it did adversely effect the bihourly counting rate thereby associating an increased statistical error with bihourly intensities recorded. Thus it was decided to set up a number of telescopes having a semiangle of opening of 5° in E-W plane and an adequate counting rate*. This could be achieved within limitations by using single-counter telescopes having a length of 30 cm diameter of 4 cm with end-trays separated by 40 cm. A detailed description of the arrangement of the counter telescopes is given in section 2.111 below.

Having fixed the telescope configuration, the problem arose of designing electronic circuits which could be operated on batteries since A.C. mains at Gulmarg fluctuates over wide limits (90 volts to 230 volts) and there are frequent interruptions during the course of the

* At that time the author was not aware of the influence of the angle of opening in N-S plane on the form of solar daily variation.
day. This, in turn, required that the power consumption by valves of the circuits be kept to a bare minimum.
From the list of battery operated valves, it was found that DL 67 electronic tube (manufactured by Philips Limited) was just the valve which consumed the least power on both H.T. and L.T. side and at the same time could give a performance commensurate with the requirements of the electronic circuits used for continuous recording of cosmic rays. Hence all electronic circuits, the details regarding which find place in the ensuing pages, were designed using DL67 electronic tubes. The filament of this tube requires only 1.3 MA of current at 1.2 volts and an H.T. as low as 22.5 volts is enough. However, pulse height and stability considerations led the author to operate these circuits from an H.T. of 90 volts. But in case of recording stage, relatively high current was required because the 'telephone-call' type mechanical recorders which were used to register cosmic ray counts, require a minimum of 15 mA to actuate them. Nevertheless the author could still economise on power consumption by using cold cathode tube type QA4G which does not require any filament current.

After completing the construction of various circuits the equipment was given a trial run for two months during which time the author satisfied himself about the proper running and stability of operation of the various circuits. The unit started operating, on regular basis, from
31st December 1955. The author shouldered the responsibility of its maintenance up to 31st January 1956.

In the earlier stages of the work, the author received generous assistance and helpful advice from Dr. U.D. Desai, the Reader in Electronics.

2.111. The layout of the apparatus

The schematic diagram of the experimental set up of telescopes having an aperture of $10^\circ \times 112^\circ$ is shown in Figure 5.

![Diagram of the layout of the apparatus](image)

* $10^\circ$ = apex angle of the cone in E-W plane and $112^\circ$ = apex angle of the cone in N-S plane.
Triple coincidence system of recording was used. Each telescope (T) consists of three one-counter trays A, B, C mounted vertically one above the other at a distance of 20 cm. from each other; the extreme trays being thus 40 cm apart. Self-quenched type counters were used. The length of each counter was 30 cm and its diameter 4 cm; the total sensitive area for each telescope being 120 cm$^2$. There were eight such telescopes T1, T2, etc.).

The alignment of the telescopes was such that the cross-section of the end-on position of the counters lay in the E-W plane whereas the cross-section of the broad side-on position of the counters lay in the N-S plane. The respective semi-angles of the cones defined by the extreme trays in the two planes was $5^\circ$ and $56^\circ$. To eliminate the soft component, 10 cm of lead absorber was interposed between middle and the bottom trays. Unsealed counting rate of each telescope was 1200 per hour.

With a view to keeping the recording arrangement as simple as possible and to economise on power consumption the use of conventional quenching unit was dispensed with and resistance quenching system was used*. The quenching resistances also formed the grid leaks of the coincidence unit. The output pulses from the trays $A_1, B_1, C_1; A_2, B_2, C_2; \ldots \ldots$ were fed to the coincidence units.

* This type of arrangement was made possible by use of good quality GM counters which were prepared by the author himself. The method of preparation has been described in Sec. 2.121.
Output of the coincidence units were fed to level-discriminators in twos e.g. the output of $C^X_1$ and $C^X_2$ was fed to $D_{1,2}$; wherefrom it passed on to the scalers $S_{1,2}$ etc. and thence, through an isolator $Iso_{1,2}$ etc. to the recorders $R_{1,2}$ etc. The dials of the mechanical recorders (the mechanical recorders were all mounted on a panel) were photographed at hourly intervals by an automatic, battery operated, photographic arrangement which makes use of a 16 mm aircraft camera. Details regarding various circuits is given in Sec. 2.3.

The inherent simplicity of the arrangement described above led to great amount of convenience in the maintenance of the unit.

2.113 Response characteristics of the telescopes

One of the principal characteristics of the counter telescope is its directional pattern, or more exactly, the function $I(\theta)$; showing the relation between the intensity of particles recorded by the given instrument and the angle $(\theta)$ between the direction of their motion and the zenith. The knowledge of $I(\theta)$, apart from aiding other calculations (e.g. the theoretical grouping of the output pulses from coincidence unit of the telescopes $T_1, T_2, T_3, \ldots$ etc. into pairs, was undertaken to enable the author to use lesser number of recording stages with obvious economy in power consumption and electronic components. All this was achieved without impairing the efficiency of operation of the arrangement.
calculation of barometric coefficient etc.), enables one to locate the position of extraterrestrial source of various variations of cosmic rays with respect to a particular geometry of the counter telescope.

\( I(\theta) \) may be calculated in many different ways as suggested by various authors e.g. Witmer and Pomerantz (1948), Newell and Pressly (1950), Blokh and Dorman (1957) and Brumberg (1958). Author has followed Newell and Pressly's method of calculation and the results for the telescope configuration used by him are indicated in Figures 6(a), 6(b) and 6(c).

Fig. 6(a) & 6(b) give the response characteristics of the telescope.

Fig. 6(c) gives the contributions made by different arbitrary areas to the total counting rate of the telescope.


diagram
Figure 6(a) shows that 55% of particles are confined to 1/5 of the total solid angle subtended by the telescope. Figure 6(b) gives the percent of particles confined within various arbitrary fractions of the total solid angle. Figure 6(c) gives the contributions made by different arbitrary areas (defined by angles subtended by them in two mutually perpendicular planes) to the total counting rate of the telescope. Figure 6(b) would be, later, used for calculating the position of the source of diurnal component of solar daily variation from the data obtained from meson counter telescopes operated at Gulmarg during 1956 and 1957.

2.12 Self-Quenched Geiger-Muller Counter

The self-quenched type of Geiger counter is essentially a diode, filled with an inert gas, argon and a polyatomic vapour* like ethyl acetate, which operates in the region of the unstable corona discharge. The arrangement, in active state, being so sensitive that the formation of a single pair of ions anywhere within its confines is sufficient to trigger a discharge; the magnitude, duration, and general character of which are independent of the specific ionizing power of the

* For satisfactory performance the polyatomic vapour should have (i) low ionization potential compared to the monatomic inert gas and (ii) a broad and intense ultraviolet absorption band which should enable it to dissociate rather than emit radiation when in an excited state.
ionizing particle. Montgomery (1940), Stever (1942), Wilkinson (1950) and Korff (1955) have discussed, in an exhaustive manner, the process of the development of the discharge and its quenching in a self-quenched Geiger counter.

When an ionizing particle passes through such a counter, in active state, it produces a few ion pairs in the sensitive volume of the counter. The electrons so freed trigger a discharge which spreads rapidly throughout the length of the counter. The discharge, however, lasts only a few microseconds. Soon the field conditions inside the counter are altered due to the formation of a sheath of positive space charge in the high field sensitivity region near the central wire and the discharge is extinguished. A small voltage pulse is developed, in this process, across the counter and this can be easily detected and recorded by electronic circuits.

The important requirements that such counter should meet are, that they have low operating potential, long operating range, high efficiency, stability with use and time, large pulse size and short recovery time. In practice, however, a workable compromise has to be made between these stringent requirements depending upon the purpose for which these counters are to be used. For time-variation studies the primary requirements are
that the counter should have a long life and that their characteristics should not change significantly during the course of their useful life.

2.121 Preparation of self-quenched Geiger counters

A typical self-quenched Geiger counter used by the author consisted of a pyrex glass tube 30 cm long, 4 cm in diameter along the axis of which was stretched a fine tungsten wire 4 mils (1 mil = 2.5 x 10^{-3} cm) in diameter which serves as an anode. The cathode consisted of a cylindrical copper sheet. Thin glass sleeves were introduced at the ends to confine the sensitive area of the counter within well defined limits. The whole assembly was thoroughly baked in an oven to drive out the adsorbed gases.

The chief cause of the deterioration of the counter characteristics is often the multiple pulses which arise because of the photosensitivity of the cathode. Multiples also adversely affect the useful life of the counter. So the chief problem in producing good counters involves devising means of diminishing and if possible eliminating the photosensitivity of the cathode. If a quenching unit is used in conjunction with the counter, this problem is relegated to the background because in that case, after every discharge the voltage across the counter is automatically kept far below the
threshold till the discharge is completely quenched and hence we get a single pulse in the output for every discharge. But if one decides to use resistance quenching system, as the author did, it becomes rather imperative to take special care in treating the cathode so as to reduce its photosensitivity. The author succeeded in doing this by subjecting the cathode to a chemical treatment suggested by Curran and Craggs (1949). It involved the use of three solutions. Complete details regarding the composition of these solutions together with the procedure followed is given in the appendix attached at the end of this chapter.

At the end of the desensitizing treatment the counter was washed properly and dried and then evacuated by a rotary oil pump and filled with a mixture of argon (90%) and ethyl acetate (10%) to a total pressure of 10 cm. of Hg. After allowing sufficient time for the gases to admix, the counter was tested for plateau and only those which showed a plateau of a minimum of 200 volts, were considered acceptable. They were next left for aging overnight and re-tested in the morning. Only those counters the characteristics of which remained unaltered after aging were finally accepted.

A typical counter prepared in this way had a threshold at about 1150 volts, a practically flat plateau of 200 volts, an useful life of six to eight
months during which time few multiples appeared in the output. The efficiency of such counters was found to be \(99.5\%\).

Old rejected counters need not be subjected to the desensitizing treatment again. It is enough to just refill them. At the time of refilling, the counter was merely rinsed with distilled water to rid the cathode and the walls of the counter, of decomposition products of polyatomic vapour. Also, following Shepard (1949), the central wire was heated to a dull red heat. This procedure restored most of the counters to their original characteristics.

2.13 Electronic circuits

2.131 Coincidence circuit

It is designed after the well-known Rossi (1930) type circuit. An important property of such a circuit being that a large output pulse (positive) is obtained only when the input pulses (negative) from various (say n) channels arrive within a few microseconds of each other. Of necessity the difference in the output resulting from n-fold and (n-1)-fold coincidences has to be rather large so that it is easy to discriminate between them. The author used a triple coincidence i.e. \(n = 3\), circuit shown in Figure 7. The circuit
has a resolving time \( \sim 7 \times 10^{-6} \) sec. and a ratio of three-fold to two-fold coincidences greater than 15.

Fig. 7 - Coincidence unit.

Attached to the coincidence circuit was a 'level-discriminator' which also acted as phase inverter. The output from this stage had the same sign (negative) as that of the input pulses arriving at the grid leaks of the coincidence unit.

2.132 Scaling Circuit

It consisted of a suitable number of Eccles-Jordan type bistable multivibrators put in cascade. An ideal bistable circuit should, if possible, have a high
triggering speed, a high trigger sensitivity, a low power consumption, a good stability, and a low sensitivity to extraneous interferences. All these demands, however, cannot be satisfied at the same time, as an improvement of one or more of the properties mentioned results in a deterioration of others (e.g. see the detailed analysis made by Neeteson 1956). Therefore, general rules for designing a bistable multivibrator are difficult to formulate. Many investigators e.g. Stevenson and Getting (1937), Lifschutz and Lawson (1938), Reich (1938), Higginbotham et al (1947), Fitch (1949) etc., have described varied methods of increasing the switching speed and improving the general reliability of such circuits. Ritchie (1953), and Pressman (1953) have described an elegant design procedure.

Battery operated binary type scaler designed by the author is shown in Figure 8. The chief features of the circuit being very low power consumption both on H.T. and L.T. side and a tolerably good resolving time. Diode input feed to the plate circuit was used because such an arrangement improves the stability of the scaler and at the same time it also immunizes the circuit to extraneous interferences.

Apart from providing a low output rate corresponding to a high input rate, the scaling circuit helps to change the random distribution of pulses into one where the different pulses are more regularly spaced; this facilitates the recording of the pulses on the output
side by "telephone call" type recorders, which have a rather low resolving time (~ 0.2 sec.). As shown by Alaoglu and Smith (1938) the time interval between every \( r \)th pulses will have standard deviation given by 
\[
(1-r)^{-\frac{1}{2}}
\]
so that as \( r \) increases the \( r \)th pulse will be more regularly spaced.

Fig. 8 - Scaling Unit.

2.133 Isolating Circuit

The output pulses of the scaler are fed to an 'Isolator' which consists of a grounded-grid triode. The necessity of using 'Isolator' arose because when the cold cathode tube of the recording stage is triggered, a continuous discharge occurs between the plate and the cathode of the tube. So that if output is
fed to the recording stage straight from the last stage of the scaler, a feedback is likely to occur from the former to the latter. Isolating stage prevents this by acting as a buffer between the scaling stage and the recording stage. It presents an infinite impedance for any feedback that might take place between the grid circuit of the cold cathode tube, and the scaling stage.

2.134 Recording Circuit

As shown in Figure 8, it consists of a cold cathode tube (type OA4-0) biased to a little below the 'break-down' point and in the plate circuit of it is put an electromechanical recorder in series with an energising relay (R). A mechanical switch (S) operated by the energising relay serves as triggering mechanism for the recorder.

The output pulses from the Isolator trigger the cold cathode tube and a current of the order of 15 m.A. flows through the plate circuit thereby energising the electromechanical recorder and the relay (R). The latter, in turn, operates the mechanical switch (S) which cuts off the H.T. connection leading to the extinction of discharge in cold cathode tube. In the meantime, the recorder has registered one count. The circuit is thus ready to receive another triggering signal. The mechanical recorders were mounted on a panel which was photographed by an automatic battery operated photographic device.
2.14 Testing of the proper running of the apparatus

The routine checks for the satisfactory working of the apparatus consisted of the following tests.

(1) Tray rates of all the counter trays were taken daily to ensure that counters were working satisfactorily. Besides at the end of every month, even if the arrangement were working satisfactorily, plateau of all the counters was taken. In case of any counter failure, plateau was taken of all the counters comprising the particular telescope.

(2) Daily measurement of the following D.C. voltages:
   (a) Filament voltages.
   (b) Grid Bias voltages.
   (c) Plate voltages.

(3) Periodic checks on the satisfactory working of mechanical recorders.

(4) Visual inspection on an oscilloscope of the shapes and the sizes of the input and output pulses from various electronic circuits.

These checks were found sufficient to obtain stream lined performance from the various constituent
units of the apparatus.

2.2 Recording of Nucleonic Component

2.21 Introduction

After having come back from Gulmarg in 1958, the author undertook the responsibility of the maintenance of the Ahmedabad neutron monitor pile for the period May-December 1958, as a part of author's contribution towards the I.G.Y. effort of the Physical Research Laboratory at Ahmedabad.

The experimental arrangement of neutron monitor pile was essentially similar to that described by Chicago group and closely conformed to the specifications laid down by SGRIV for the recording of the nucleonic component during the last I.G.Y.

The entire neutron monitor pile along with associated electronic circuitry was assembled by the author's predecessor Mr. Satyaprakash Gupta. The proportional counters filled with boron trifluoride (enriched with B\textsuperscript{10} isotope) were also prepared by Mr. Gupta according to a technique of filling developed by him in collaboration with Prof. H.V. Neher of California Institute of Technology (1957), which work was essentially an extension of Prof. Neher's earlier work (1954) in this direction.
2.22 The Neutron Detectors

The neutron component may be registered by means of proportional counters filled with boron trifluoride, the interaction of which with neutrons leads to the reaction:

\[ \text{B}^{10}_5 + \alpha \rightarrow \text{Li}^7 + \text{He}^4 + Q_1 \]

where \( Q_1 \) is the energy liberated in the reaction = 2.5 MeV; about 1.6 MeV goes to \( \alpha \)-particle and about 0.9 MeV to \( \text{Li}^7 \) nucleus (Veksler 1950). The two fragments travel in opposite directions and form about 80,000 ion pairs if mean-free-path is fully utilized. For a counter whose gas multiplication is unity and which has a capacity \( \sim 10^{-5}\mu\text{F} \), the pulse developed will be approximately one microvolt. Hence a counter with gas multiplication \( \sim 10^3 \) (which is normally attained in practice) will develop a pulse large enough to be recorded.

Natural boron consists of a mixture of two isotopes, \( \text{B}^{10}_5 \) (about 20%) and \( \text{B}^{11}_5 \) (about 80%), but only \( \text{B}^{10}_5 \) participates in the reaction; therefore, this mixture is normally enriched with \( \text{B}^{10}_5 \) isotope (to the extent of 96%) to increase the effectiveness of the counters. The counting effectiveness is determined by the probability of neutron capture by the boron nuclei. The capture cross-section \( \sigma \), over a wide range of neutron energies, is inversely proportional to their velocity and reaches its maximum value for thermal neutrons where

\[ \sigma = 550 \times 10^{-24} \text{ cm}^2. \]
The counting characteristic of a boron counter has a wide plateau (≈ 200 volts) since pulses from the \( \alpha \) -particles are equal in value and considerably exceed the pulse size of the pulses from \( \beta \) -particles and other ionising particles of cosmic rays. It is important to note that, since only a single nucleus of isotope \(^{10}\text{B}\) is consumed for each instance of recording, the service life of the counter is practically unlimited for the recording of neutrons in cosmic rays.

The neutrons may be detected by boron-trifluoride proportional counters with either the atmosphere acting as a moderator or by surrounding the counters with a moderating material like paraffin or carbon. In the first case slow neutrons (energy \( \sim \text{keV} \)) are detected and the arrangement is called a 'slow detector', whereas in second case fast neutrons (energy \( \sim 1 \) to 20 MeV) are recorded and the arrangement is termed a 'fast detector'.

To get a foolproof system of recording which is not affected by atmospheric or local conditions, a process called 'local generation' of neutrons is employed. In this case \( \text{BF}_3 \) counters are enveloped in a small thickness of moderator and are surrounded by 'condensing material', the whole of this assembly being shrouded by an increased thickness of moderator which serves as an outer cover. In such arrangement the detected neutrons are mainly those which are produced inside the 'condensing material'.
through local nuclear fission. It is found that the greater the atomic weight of the 'condensing material' the larger the number of secondary neutrons produced e.g. the ratio of neutron multiplication (mean number of neutrons emitted in low energy nuclear fission) in lead to the multiplication in graphite is about 8:1 (cf. Tongiorgi 1949, Montgomery et al 1949). So generally lead is used as condensing material with paraffin as moderator to decelerate the neutrons generated in lead. The assembly of local neutron producer (lead), a moderator (paraffin) and a neutron detector, is termed a 'neutron monitor pile'.

2.221 The Neutron Monitor Pile

The optimum thickness of condensing material and the moderator to be used to set up a neutron pile has been studied by several workers e.g. Tongiorgi et al (1949), Montgomery et al (1949), Cocconi et al (1950), Adams and Braddock (1951) and Simpson et al (1949, 1953).

Simpson et al have found that the optimum thickness, \( l_1 \), of moderator between lead and BF\(_3\) counter (See Figure 9) is about 3.2 cm. The lead thickness, \( l_2 \), is taken arbitrarily as 5.1 cm. to take account of the fact that \( l_2 \) should be greater than the local transition maximum but at the same time the attenuation of 'star' producing radiation should not be large.
The paraffin surrounding the lead - paraffin - counter assembly is primarily meant for stopping extraneous disintegration neutrons produced outside the neutron pile from reaching the counters, but it also acts as a moderator and reflects back the neutrons produced in lead which tend to escape.

Fig. 9 - Neutron Monitor Pile.

The thickness, $l_3$, of this paraffin was determined empirically by the aid of a Ra-Be source placed outside the pile. The increase in $l_3$ for each 3.8 cms. resulted in a decrease in the count of neutrons arriving at the detector from outside by a factor of 2. The thickness $l_3 = 15.2$ cms. was selected and was entirely sufficient to assure effective slowing and scattering of the neutrons formed in lead.
2.222 Characteristic of the Neutron Monitor

Though the disintegration neutrons are emitted isotropically from lead nuclei and scattered by the moderator in all directions, the high energy star producing radiation (Nucleonic Component of cosmic rays) is peaked in the vertical direction in the atmosphere (the angular distribution near sea level varying as \( \cos^n \theta \), with \( n \approx 4 \) to 5). Thus, neutron pile measurements correspond to the primary particles arriving vertically at the top of the atmosphere.

Studies (Simpson et al. 1953) have shown that about 84% of recorded neutrons are formed in lead, 13% in paraffin, and only 3% make up the background of the counters and neutrons arriving at the detector from outside.

Fig. 10 - Block diagram of the pile and the recording system.
Neutron pile at Ahmedabad consists of two sections (A,B) each having three BF$_3$ counters and each section has an independent electric pulse recording system. The layout of the pile and the recording system is shown in Figure 10.

2.23 Electronic Circuits

All the circuitry at Ahmedabad, unlike that at Gulmarg, was operated by A.C. mains supplying 230 volts A.C. To reduce the voltage fluctuations in the mains to a bare minimum, the input to various circuits was derived from a constant voltage power transformer which was fed from the A.C. mains.

2.231 Pulse Amplifier

The function of an amplifier, used in conjunction with a boron trifluoride counter is to accept and amplify the pulses produced in the counter by neutrons and by other ionizing radiations. The pulses may be of the order of a few hundred microvolts and have to be amplified to a level of a few volts so that discrimination can be made, to high degree of accuracy, between the pulses produced by the capture of neutrons by B$^{10}$ and those produced by background radiation.

Elmore and Sands (1949) have given an exhaustive account of the theory of various types of amplifiers and the relative merits and limitations of each of them. The
basic requirements of the amplifier, for our purpose, is that it be capable of handling randomly distributed pulses at a high mean rate of recurrence, it have a large signal to noise ratio and a fairly steady gain. These demands are reasonably satisfied by wideband Feedback type Amplifiers.

The amplifier used by the author is shown in Figure 11(a). The circuit consists of two sets of two stage feedback loops, each having a gain of about 20, connected in cascade. Short time-constant RC network (≈ 5.0 × 10⁻⁶ sec.) was introduced between the two stages and another with about 50 microsecond for connecting the counter to the first loop of the amplifier. A small
resistance of 470 ohm. was also introduced as a stopper between the grid of the first tube and the condenser feeding counter pulses to the first loop to suppress parasitic oscillations. The upper and the lower half power frequency of the amplifier are 500 Kc/sec and 30 Kc/sec, respectively.

2.232 Pulse Height Discriminator

The chief requirements of such a unit are:

(i) It should be able to discriminate reliably between pulses that differ in amplitude by a small fraction of a volt and hence the amplitude at which discrimination occurs should be stable to a similar extent.

(ii) It should be capable of accepting narrow pulses, such as those produced by the pulse amplifier.

(iii) It should present a high impedance to the signal source and respond to each of the many pulses that follow each other in rapid succession.

(iv) It should not overload on a pulse of amplitude much greater than critical amplitude i.e. it should not distort large signals that it receives, nor should its operation depend upon the size of previous input pulses.

(v) It should have an easily adjustable discrimination level.
Various types of balanced pulse height discriminators which can handle pulses as large as 100 volts have been described in literature (e.g., see Elmore and Sands, 1949). These circuits have hysteresis of about 1 volt and the bias voltage is reliable to within 0.1 volt over a long interval of time. In our case, however, the requirements of the discriminator were not so stringent since it was required to handle pulses that were fairly uniform in size and hence the simple discriminator circuit as used by Simpson (1955) was found to be good enough for the purpose. An added advantage of such circuit was that whereas more refined circuits require pulses of about 20 volts, this circuit could be triggered reliably even with negative pulses of about 1 volt which, in turn, enabled the gain requirement demanded of the pulse amplifier to be reduced by a factor of 20.

The discriminator used is shown in Figure 11(b). It consists of a cathode coupled monostable multivibrator which, when triggered remains in the unstable state for a few hundred microseconds and gives a pulse big enough to drive a scaling circuit.

2.233 Scaling Circuit

A high speed scaling circuit was used and is shown in Figure 12(a). Neon indicators were used for visual inspection of the proper functioning of the scaler.
2.234 **Recording Circuit**

The cascade of scaling units was followed by a recorder driving circuit as shown in Figure 12(b) alongside the scaling circuit. It consists of a power pentode biased below cutoff. Pulses from one of the plates of the twin triode of the last stage of the scaling unit are fed to the grid of this tube. The tube actuates an electromechanical recorder whenever a positive pulse arrives at its grid.

2.235 **Automatic Photographic Device**

The raw cosmic ray data were obtained by photographing, every hour, the dials of the mechanical
recorders mounted on a panel alongside which were fixed a clock and a calendar. This panel formed one end of a light-proof box, blackened from inside, containing two bulbs (having proper wattage) to illuminate the panel when required. On the opposite side of the box a detachable camera was attached which took photographs of the panel, at hourly intervals, on 35 mm. film.

![Camera Unit Diagram]

Fig. 13 - Camera Unit.

The film was moved by a sprocket attached to a shaft which protrudes outside the camera and was coupled to a low-speed motor which rolled the film through one frame after each exposure. This was done with the help of a relay arrangement triggered by an electrical contact of a few seconds duration made hourly by a clock. The
Camera unit is shown in Figure 13.

Figure 14 shows the relay control circuit used for exposing and winding the film at hourly intervals. It consisted of two triggered thyratron switches working in succession.

Fig. 14 - Automatic sequence control circuit.

Every hour the clock gave a positive pulse of 150 volts to the grid of the first thyratron (left) which is normally biased negative. The current passing through this thyratron energises the relay A, thereby making the bulb contact which flashes momentarily. At the same time plate circuit of this tube is made open and so its discharge is extinguished and this, in turn, 'opens' the relay(A) circuit thus switching off the lamps. The pulse from the
plate of the first tube triggers the second thyatron (right) thus energising the relay B which, in turn, puts on the motor. An internal switch of the motor cuts off H.T. connection from the plate of the second tube; however, before this happens the film has moved by one frame. After these successive operations the circuit reverts to its original state.

At a time; the camera can hold 50 ft. of film. Everyday, at 9 a.m., the exposed film of the previous day is removed and developed. The readings of the dials of the mechanical recorders are then noted for odd bihours from the negative film.

2.236 Power Supplies

High Voltage Supplies. To achieve high stability in the working of electronic units and of BF3 counters stabilisation of all D.C. voltages against line voltage fluctuations and load variations is very necessary. A complete analysis of stabilising circuits is given by Hunt and Hickman (1939) and Gilvary and Rutland (1951).

A degenerative type of regulating circuit is the most suitable for getting a close control over the output voltage, a high stabilising ratio, and a low internal impedance. Figure 15 shows the high voltage supply used by the author. It consists of a half-wave rectifier, with
a RG type filter, feeding about 3500 volts to the degenerative regulating network which gives a variable output in the range of 1800 to 3000 volts.

**Fig. 15 - High voltage supply.**

*Low voltage supplies.* Although the degenerative type of regulating circuit is generally used in low voltage supplies; in applications where the current load is relatively small and the variations in the load are limited, a VR tube stabilisation can be used. The maximum current which can be drawn from a VR tube regulator depends upon the maximum current which can be passed through the VR tube (which is of the order of 40 mA), the output impedance of the filter section and the variations in the load current.
Figure 16 shows the low voltage supply used by the author. There are two sections (I and II) of VR tube regulators, one for supplying current to the amplifier and the discriminator and the other to the scaler and the high voltage supply.

2.24 Maintenance of the neutron monitor pile

The maintenance of the neutron monitor pile involved the following routine checks:

(a) Calibration of the input pulse sensitivity of the amplifier using a special pulse generator which gave pulse ~ 1 millivolt, the shape of which was similar
to the one given by $BF_3$ counters. Pulse repetition rates of $1 \text{ sec}^{-1}$ to $100 \text{ sec}^{-1}$ were used for checking the performance of the scaling and the recording circuits.

(b) Every fortnight the 'plateau' was taken using a 2 mg. Ra-Be test source giving $2.7 \times 10^4$ neutrons $\text{sec}^{-1}$. For this purpose the test source was inserted in the two cavities specifically meant for it and the counting rate was taken. The operating voltage for the $BF_3$ counter was selected in the middle of the 'plateau'.

(c) During normal operation the ratio of the counting rate from A and B sections should be constant with time. Similarly, the ratio of the rates from the A and B sections for a neutron source must be constant.

From these checks and the parallel running tests (to be described in Sec. 3.1) it was possible to ascertain the proper operation of the neutron monitor pile.
2.3 APPENDIX

Chemical treatment for diminishing the photosensitivity of the cathode of GM counter

Prepare three solutions as follows:

Sol. A. 300 gm. ammonium chloride + 90 cc concentrated hydrochloric acid + 50 cc gelatin solution 0.2% by weight. These are made upto one litre in distilled water.

Sol. B. 250 gm. chromic acid + 75 cc concentrated sulphuric acid + 35 cc of Sol. A + 50 cc gelatin solution 0.2% by weight. These are made upto one litre in distilled water.

Sol. C. 250 gm. chromic acid + 75 cc concentrated sulphuric acid. These are made upto one litre in distilled water.

Procedure

1) Take 100 cc of Sol. A and heat upto 90°C. Introduce this hot solution into the counter tube and shake gently till all signs of oxidation disappear from the cathode surface. Remove the solution from the tube and rinse it thoroughly with distilled water.

2) Now introduce about 30 cc of Sol. B and shake thoroughly for about 2 minutes. Remove Sol. B and
rinse the coulter thoroughly with distilled water.

3) Introduce 30 cc of Sol. C and shake the coulter for one minute. Remove the solution and rinse the coulter repeatedly with distilled water for ten minutes. Now put the coulter for drying.

Precautions

Do not allow the Sol. A to remain in touch with the cathode for more than eight minutes, in any case.

The cathode surface gets a dull golden colour after treatment with Sol. B and a uniform matt pinkish hue after completing the treatment with Sol. C. It is probably covered with a very thin and uniform layer of oxide at this stage.