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Ronald A. Korsak

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INTENSITY OF MU-MESONS IN COSMIC RAYS - KORSAK

MEASUREMENTS OF THE INTENSITY OF MU-MESONS IN COSMIC RAYS DURING A PERIOD OF UNUSUAL SOLAR ACTIVITY

By

Ronald A. Korsak

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Physics

The University of New Mexico
1960

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

E F Castetter
Dean

June 1, 1960
Date

MEASUREMENTS OF THE INTENSITY OF MU-MESONS IN COSMIC RAYS DURING A PERIOD OF UNUSUAL SOLAR ACTIVITY

Ronald A. Korsak

Thesis committee

John R Green
Chairman

Roy Thomas

Victor H. Regener

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LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

A. Cosmic Ray Telescopes Using Liquid Scintillators

About ten years ago, investigators began to employ liquid scintillators as charged particle detectors.[1] The chief advantage of solution scintillators, that is, of liquid or plastic scintillators, over the crystal scintillators which had been used previous to that time, is that solution scintillators can be made with much larger areas or volumes than can be obtained feasibly with crystals. In much experimental work, and particularly in the study of cosmic rays, where many of the events in which one is interested are relatively rare and where a great deal of data is required for statistical reasons, large detector volumes enable the investigator to obtain the necessary data with a minimum amount of time and expense. Thus, cosmic ray telescopes using liquid scintillators as detectors afford a wide choice of types of events with high enough counting rates to give reliable statistics.

Although liquid scintillators in cosmic ray telescopes can be used to give an indication of the energies of the counted particles, shower sizes, types of inter-

actions with matter, etc., they can, of course, simply be used as particle detectors to indicate the number of charged particles striking a certain area in a particular length of time and coming from a determined range of direction. If two scintillator tanks are aligned vertically with absorber placed between them, particles detected simultaneously in the top and bottom tanks will have traversed the absorber, provided that the resolving time of the scintillator is longer than the time of traversal but not so long as to include many chance coincidences resulting from separate particles traversing the tanks at very nearly the same time from directions outside the aperture of the telescope. The particles counted by observing coincidences in the two tanks will be essentially those with energies in excess of that necessary to traverse the absorber plus the material of the tanks and supports. The number of chance coincidences can be reduced by placing additional scintillator tanks between the first two, all of the tanks then being operated in coincidence. If anticoincidence tanks are used at the bottom, the energies of the counted particles can be bracketed between two energy values, but if only coincidence is required for the recorded pulse the particles counted will be those with energies in excess of some minimum energy determined by the total amount of matter traversed by the particles.

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B. Variations of Atmospheric Origin

In 1928, Myssowsky and Turwim, making electroscope measurements of cosmic radiation, found that there is a negative correlation between the intensity of the hard component of cosmic rays and barometric pressure.[2] This is in the main due to the fact that an increase in pressure corresponds to an increase in the amount of matter above the observation station; this then results in a greater probability of the secondary particles being absorbed while travelling from their region of production to the surface of the earth. A few years later, a negative correlation was found between the intensity and the temperature of the air at ground level. This has been interpreted as being due to the instability of the mu-meson, for any increase in the temperature of the atmosphere will raise the region of meson production and allow a greater chance for meson decay and a consequent reduction in the number of mesons reaching the earth. This would mean that the temperature of interest is not that at ground level, but the mean temperature between the region of production and the surface of the earth.

Work has been done on these effects by Duperier who, in attempting to find the height of the production region, found a negative correlation between the intensity and the height of the 100 mb. pressure level.[3] In later work he found, in addition to the negative temperature effect, a positive temperature effect which he

2. Variations of Mesotron [illegible]

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Work has been done on these effects by [illegible] who, in attempting [illegible] region, found a positive correlation [illegible] sity and the height of the 100 mb. [illegible] later work he found, in addition to the [illegible] ture effect, a negative [illegible] found to be associated with the mean temperature in the region between the 100 mb. and 200 mb. pressure levels.[4] This was interpreted as being due to the competition between the process of pi-meson interaction with nuclei and that of their decay into mu-mesons.

Duperier expressed his results in the form of a regression equation as follows:

$$\delta I = \beta_1 \delta B + \beta_2 \delta H + \beta_3 \delta T,$$

where δI is the deviation from mean intensity, δB the deviation from the mean barometric pressure, δH the deviation from the mean height of mu-meson production (usually chosen as the height of the 100 mb. pressure level), and δT the deviation from the mean of the temperature of the region between P, the chosen pressure level, and the $(P + 100)$ mb. pressure level. Although there has been some doubt of the validity of the interpretations leading to this formula, it has been used by many investigators because of its simplicity and the ease with which it can be used in the treatment of data by the method of least squares.

Trefall in 1955 showed that the positive temperature effect is only in small part due to the $\pi - \mu$ decay, and is largely caused by two second order effects of the $\mu - e$ decay.[5] One is due to the fact that the mean level of meson production does not coincide with the usually employed reference level, while the other is caused by the redistribution of momentum loss along found to be associated with the [illegible] in the region between the 160th and 200th [illegible]. This was interpreted as [illegible] in the [illegible] between the process of [illegible] and that of their decay into [illegible].

Duperier and [illegible] have [illegible] a regression equation as follows:

$$\delta I = [illegible]$$

where δI is the deviation of [illegible], δ[illegible] the deviation from the mean [illegible] the de-viation from the mean height of [illegible] usu-ally chosen as the [illegible], and δT the deviation from the mean [illegible] of the region between P, [illegible] level, and the (P + 100) mb. [illegible] some doubt of the validity [illegible] accord-ing to this formula, [illegible] tors because of [illegible] it can be used in the [illegible] least squares.

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In 1957, Dorman treated all of the atmospheric effects with some rigor.[7] He expresses his results in the formula:

$$\delta N^a = \beta \delta B + \int_0^{h_0} W(h)\, \delta T(h)\, dh,$$

where δN^a is the variation in intensity due to atmospheric conditions, $\delta T(h)$ is the change in temperature of the isobaric level at which the pressure is h, h_o is the pressure at the observation station, and W(h) is the "density of temperature coefficient." Graphs of W(h) are given by Dorman for various geometries of detectors.

Mathews, in 1959, showed how the atmospheric correction coefficients can be obtained more accurately by first applying to the values of the intensity a correction which is now to be discussed.[8] An approximation to the variations of primary origin is obtained by choosing a period of 30 to 40 days during which the barometric pressure curve crosses some particular value, B_o, every two or three days, and then plotting the intensity values, which have been smoothed by averaging, for the pressure B_o as a function of time. The best fitted curve through these values will yield the correction to the

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$$\delta r = .23T + [illegible]$$

where δr is the [illegible] atmospheric conditions. δ [illegible] of the isobaric level at which the pressure [illegible] the pressure at the observation station, and [illegible] "density of temperature [illegible] are given by Dorsey for various atmospheric conditions.

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Because of the incomplete understanding of the processes which cosmic rays undergo in the atmosphere, there is still no generally accepted treatment of the atmospheric dependent variations of the intensity or preferred method of establishing correction coefficients.

C. Decreases in Cosmic Ray Intensity During Periods of Solar Activity

After it had been found that the magnetic field of the earth has an influence on the primary cosmic rays (the geomagnetic effect), investigators looked for variations in the intensity associated with time variations of the earth's field. The first world-wide change in intensity was described by Forbush in 1938.[9] A decrease in intensity of about 4% occurred at widely separated stations at the time of a great magnetic storm which began on April 24, 1937. During a similar storm in 1938 he found an appreciable correlation between the changes in the horizontal intensity of the earth's magnetic field, raw data to [illegible] to

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Forbush-type decreases have been widely observed and studied. Decreases in some cases have been as large as 10%, and, while they are often associated with magnetic storms, many have occurred without magnetic storms. Conversely, magnetic storms have been observed without decreases in the intensity. This suggests that the two phenomena are not directly related, but are related through a common cause. The decreases have been observed with ion chambers and neutron detectors as well as counter telescopes. Neutron detectors are useful since the effects of atmospheric temperature are much smaller for neutrons than mesons although other difficulties arise in the use of such detectors. The polar decreases are seen to be both larger and wider than those at other latitudes as would be expected because of the trajectory dispersion at other latitudes.[11]

There appears to be a recurrence of the Forbush decreases with a 27-day period suggesting a relation with particular areas of the sun. Some work by Venkatesan indicates an association between transient decreases in and the variations in the cosmic ray intensity at two stations, but little [illegible] [illegible] [illegible] stations. Subsequent observation has shown that [illegible] [illegible] [illegible] correspondence between the variations [illegible] [illegible] of the cosmic ray intensity. These decreases, [illegible] associated with magnetic [illegible] [illegible], have [illegible] to be known as Forbush events.

Forbush-type decreases have been studied in detail and reported. Decreases in some cases have been as large as 10%, and generally they are [illegible] [illegible] [illegible] in storms, many have counted [illegible] magnetic storms. Conversely, magnetic storms [illegible] [illegible] observed without decreases in the intensity. [illegible] [illegible] both phenomena are not [illegible] [illegible] [illegible] to a common cause. [illegible] ion chambers and neutron [illegible] counter telescopes. Neutron [illegible] [illegible] [illegible] effects of atmospheric temperature [illegible] [illegible] than meson [illegible] [illegible] of such detectors. The [illegible] both larger [illegible] would be expected [illegible] at other latitudes.

There appears to be [illegible] decreases with [illegible] with particular [illegible] of the sun. [illegible] indicates an association between [illegible] cosmic ray intensity and the passage of active solar regions past the central meridian.[12] On an average, the greater the activity rating of the region, the larger the cosmic ray decrease; however, it was not found to be possible to relate specifically the decreases in terms of the characteristics of the regions, such as flares or sunspots. His work supports the view that both the Forbush events and the usual 27-day variations differ only in degree and therefore could be attributed to the same mechanism.

A great deal of work has been done with respect to the onset times of the intensity decreases, of the magnetic storms, and of solar phenomena. It may be that the major part of the intensity depression effect occurs near the peak in the solar cycle, and resembles a triggering mechanism rather than a proportional relationship with sunspot numbers.[13] A decrease in α-particles in one experiment seemed to occur after the sun had reached its maximum sunspot activity and possibly was not related to sunspot numbers or even to solar activity.[14] Some other work indicates that solar chromospheric eruptions, which are followed by geomagnetic and ionospheric disturbances and also cosmic ray intensity decreases, may also be preceded by a 1-3% decrease in intensity 24-48 hours earlier.[15] The above evidence seems to support the view that intensity decreases, magnetic storms and solar activity are related, but not by any simple correlation.

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Some recent work on the onset times of Forbush events at different parts of the world indicates a directional anisotopy that exists in the mechanism producing the decreases, at least in the early stages.[16] The depression occurs first for particles arriving from directions between 30° and 120° west of the earth-sun line.

Recent work by Fenton et al attempts to divide the intensity decreases into three classes all of which are associated with solar activity.[17] The first is the 11-year variation associated with the 11-year sunspot cycle. The second is an almost symmetrical event lasting up to two weeks and exhibiting a recurrence tendency of about 27 days. The third class is made up of decreases apparently of the Forbush-type which recover over a period of several days.

Although many theories have been suggested to account for the Forbush events and other decreases apparently associated with solar activity, none has attained general acceptance as yet. The difficulty may lie in the lack of correlation between the decreases and any particular characteristic of solar activity as has been indicated in the discussion of the experimental work.

One of the first theories was proposed by Chapman who suggested that the decreases may be caused by ring currents induced by the earth's magnetic field in a stream of charged particles emitted from the sun.[18]

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One of the first [illegible] who suggested that the [illegible] currents induced [illegible] stream of charged particles [illegible]

As the stream reaches the vicinity of the earth some of the charged particles are forced into a ring-shaped path encircling the earth. The radius of the ring is supposed to be a few earth radii and the magnetic field of the ring current is opposed to that of the earth in the region between the earth and the ring. This would then produce the observed decrease in the horizontal intensity of the magnetic field at the surface of the earth. Outside the ring the earth's field is reinforced; this will cause more particles to be deflected away from the earth. A number of studies with respect to the ring theory have indicated that the effect would be too small to account for the decreases and, depending on the position of the ring, could even cause increases.[19] Also, the observation by Singer in 1951 of a magnetic storm decrease at Thule, Greenland, near the geomagnetic pole could not be explained on the basis of ring currents.[20]

Some work has followed the lead suggested by Alfven in 1946 that the decreases are more directly associated with the polarization of neutral but ionized beams of particles emitted by the sun.[21] The intensity variations are supposed to be due to the deceleration of cosmic ray particles passing through the electric fields caused by magnetic fields carried along by the corpuscular beam. This theory has been criticized by a number of workers because of the necessary assumptions with regard to the magnetic field carried by the beam, the general field

As the stream reaches the [illegible] the charged particles [illegible] encircling the earth. [illegible] to be a few earth radii out [illegible] ring current is presumed [illegible] gion between the [illegible] produce the observed decrease [illegible] sity of the magnetic field [illegible] Outside the ring the earth's field [illegible] will cause more particles to [illegible] earth. A number of studies [illegible] theory have indicated that [illegible] to account for the decrease and [illegible] tion of the ring, [illegible] the observation by [illegible] decrease at Thule, Greenland, [illegible] could not be explained on the [illegible]

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An approach which is perhaps more satisfactory was indicated by Morrison in 1956.[22] Instead of an ordered magnetic field in the beam, a state of magnetic turbulence is assumed. If high enough values of the fields occur, the diffusion times of the cosmic rays into the beam will be sufficient to cause a decrease when the beam envelopes the earth. Parker modified this view by suggesting that a turbulent magnetic cloud could be captured and held to the earth by the gravitational field.[23] This serves to lessen the requirements for high values of the turbulent fields.

Singer, in 1957, suggested a model with a turbulent cloud which is expanding and in which the cosmic rays are reflected back and forth where the fields are decreasing, the particles being decelerated by the induced electric fields.[24]

Also in 1957, Dorman presented a refinement of the approach first indicated by Alfven.[25]

More recently Piddington has suggested a model to explain the variations in which the radial field from a sunspot region is drawn out past the earth's orbit to form a magnetic cone with closed ends.[26] In an example he cites, irregularities in the cone separated by approx-

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imately half an astronomical unit are capable of deflecting 15-Bev. protons up to 20° and completely scattering 1.5-Bev. protons.

As yet no theory to explain the Forbush-type decreases and other decreases has been generally accepted and the problem still holds much theoretical interest. In spite of the many attempts to relate the decreases to particular aspects of solar activity, no strong correspondence has been found, and it appears that the decreases may be due to some sort of beam which allows a considerable variation in its structure when it approaches the vicinity of the earth as compared to its structure at its source on the sun. This probably accounts for the difficulty in formulating a satisfactory theory.

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CHAPTER II

APPARATUS

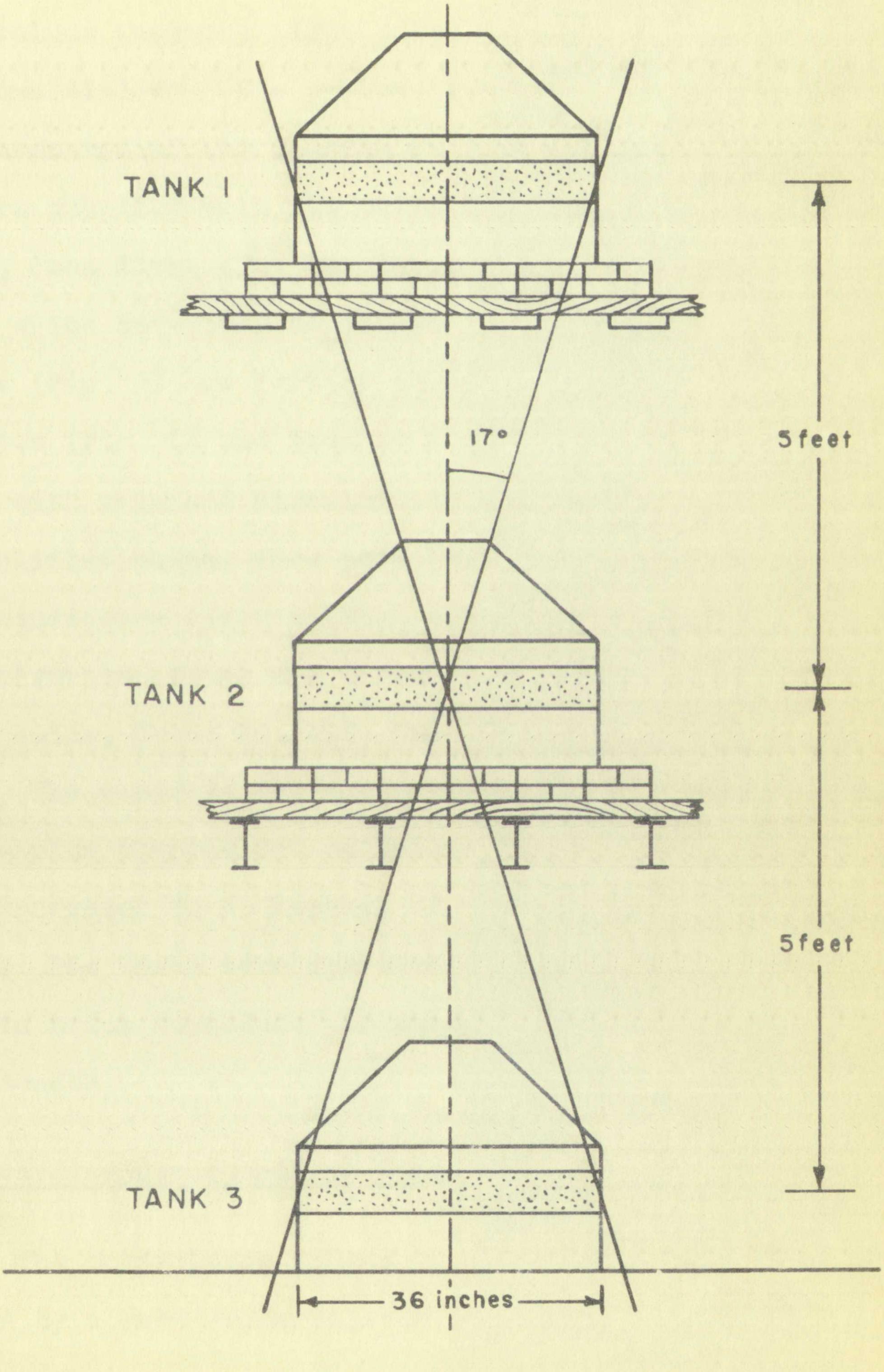
A. The Telescope and Associated Circuitry

The telescope consists of three liquid scintillator tanks supported vertically (Fig. 1). The scintillator solution volumes are cylindrical in shape, 36 in. in diameter by 5 in. deep, and are placed with a vertical distance of 10 ft. between the centers of the top and bottom volumes; this placement results in a vertical half-angle of 17°. A total of 8 in. of lead absorber is used, 4 in. of absorber between the top and middle tanks and 4 in. between the middle and bottom tanks.

The scintillator tanks are each in the form of a cylinder, 36 in. in diameter by 8 in. deep, with support 7 in. high, surmounted by a cone narrowing at the top to a flat ring, 9 in. in diameter with a centered hole, 4.5 in. in diameter (see Fig. 1). The bottom of the tank, the side and support are made of 12 gauge steel, the cone side of 16 gauge steel, and the top ring of 1/4 in. steel plate. The tanks are coated on the inside with a special protective and reflective compound.

The scintillator solutions are composed of 4.27 gm.

Fig. I. Diagram of the Telescope



of p-terphenyl and 0.123 gm. of POPOP, [1, 4, -bis-2(5-phenyloxazoyl)-benzene], per liter of toluene.

A block diagram of the apparatus is shown in Fig. 2. The passage of a charged particle through a scintillator volume causes a light pulse which is detected by a photomultiplier. The photomultipliers are DuMont 6364 tubes cemented at the opening in the top of each tank. They are supplied with 900 volts by a Model 403M Power Supply, John Fluke Mfg. Co. Inc., Seattle, Washington. Pulses which have been amplified in the photomultiplier circuit (Fig. 3) are further amplified first by a preamplifier (Fig. 4) and then by a linear amplifier-pulse shaper with gain and discriminator controls (Fig. 5). The amplified pulses from each tank are then combined in a coincidence circuit (Fig. 6). The voltage for the above circuits, which are transistorized, is supplied by wet cells, Delco No. 412, Delco-Remy, Anderson, Indiana. The circuits for the preamplifiers, linear amplifier-pulse shapers and coincidence circuit were designed by Professor V. H. Regener of the University of New Mexico. The tanks were operated in three-fold coincidence in order to reduce the number of pulses from chance coincidences.

B. Recording Equipment and Circuitry

The coincidence pulses from the telescope are counted by a Beckman/Berkeley Electronic Counter, Model of p-terphenyl and 0.1[illegible] gm. of [illegible] [1, 4-Di-[illegible] phenyloxazolyl)-benzene], per liter of toluene.

A block diagram of the [illegible] is shown in Fig. 2. The passage of a [illegible] through the scintillator volume causes a light pulse which is detected by a photomultiplier. The photomultipliers are [illegible] tubes cemented at the opening of the top of each tank. They are supplied with [illegible] volts by a [illegible] Supply, John Fluke Mfg. Co. Inc., Seattle, Washington. Pulses which have been amplified in the photomultiplier circuit (Fig. 3) are further amplified first by a pre-amplifier (Fig. 4) and then by a linear amplifier-pulse shaper with gain and [illegible] control (Fig. 5). The amplified pulses [illegible] in a coincidence circuit (Fig. 6). The voltage for the above circuits, which are [illegible], is supplied by wet cells; [illegible] No. [illegible], [illegible]. The circuits for the pre-amplifiers, linear amplifier-pulse shapers and coincidence circuit were designed by Professor V. H. [illegible], University of New Mexico. The tanks were operated in three-fold coincidence in order to reduce the number of pulses from chance coincidences.

B. Recording Equipment [illegible]

The coincidence pulses from the [illegible] are counted by a [illegible]

Fig. 2. Block Diagram of the Apparatus

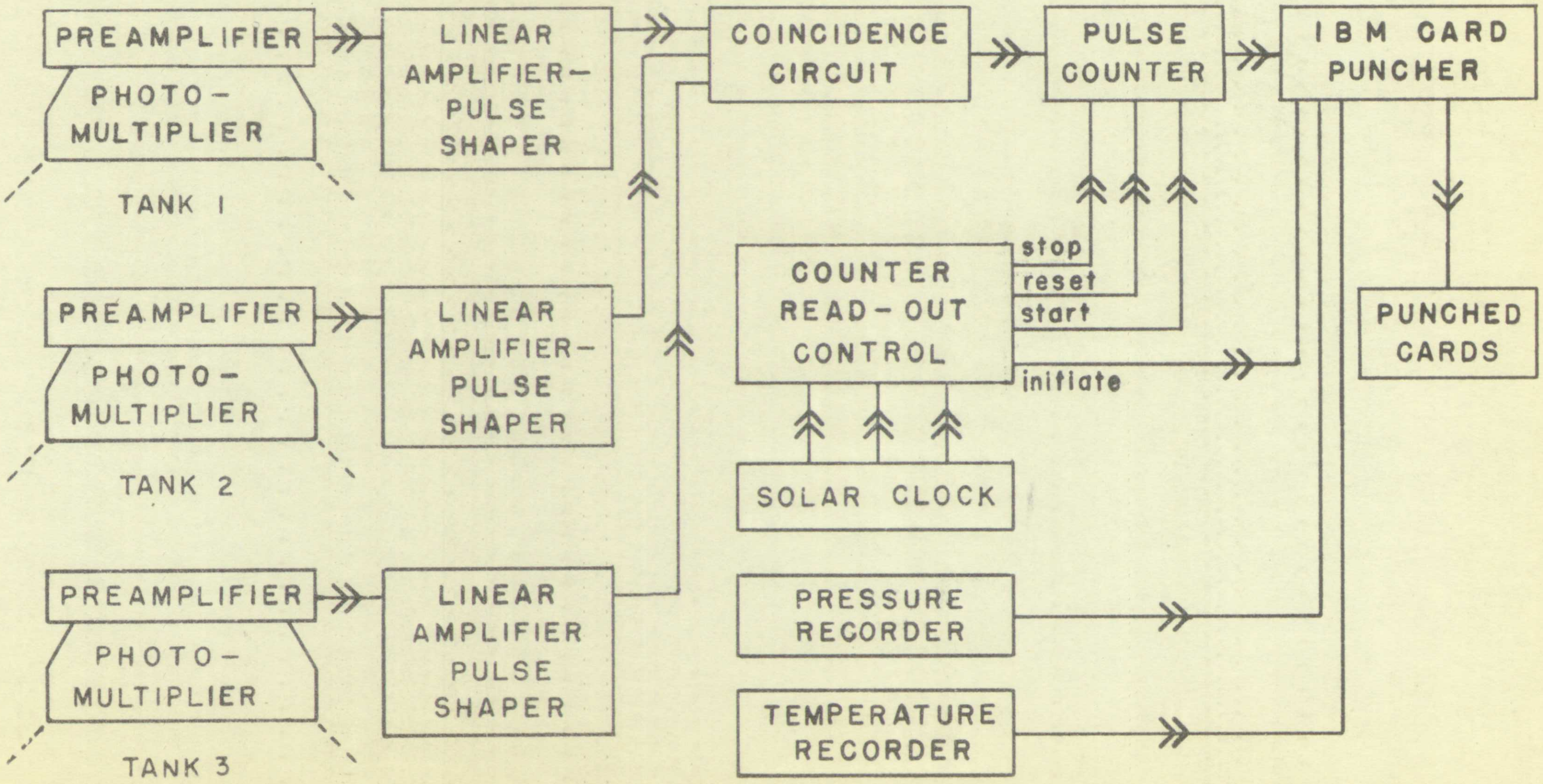


Fig. 3. Photomultiplier Circuit

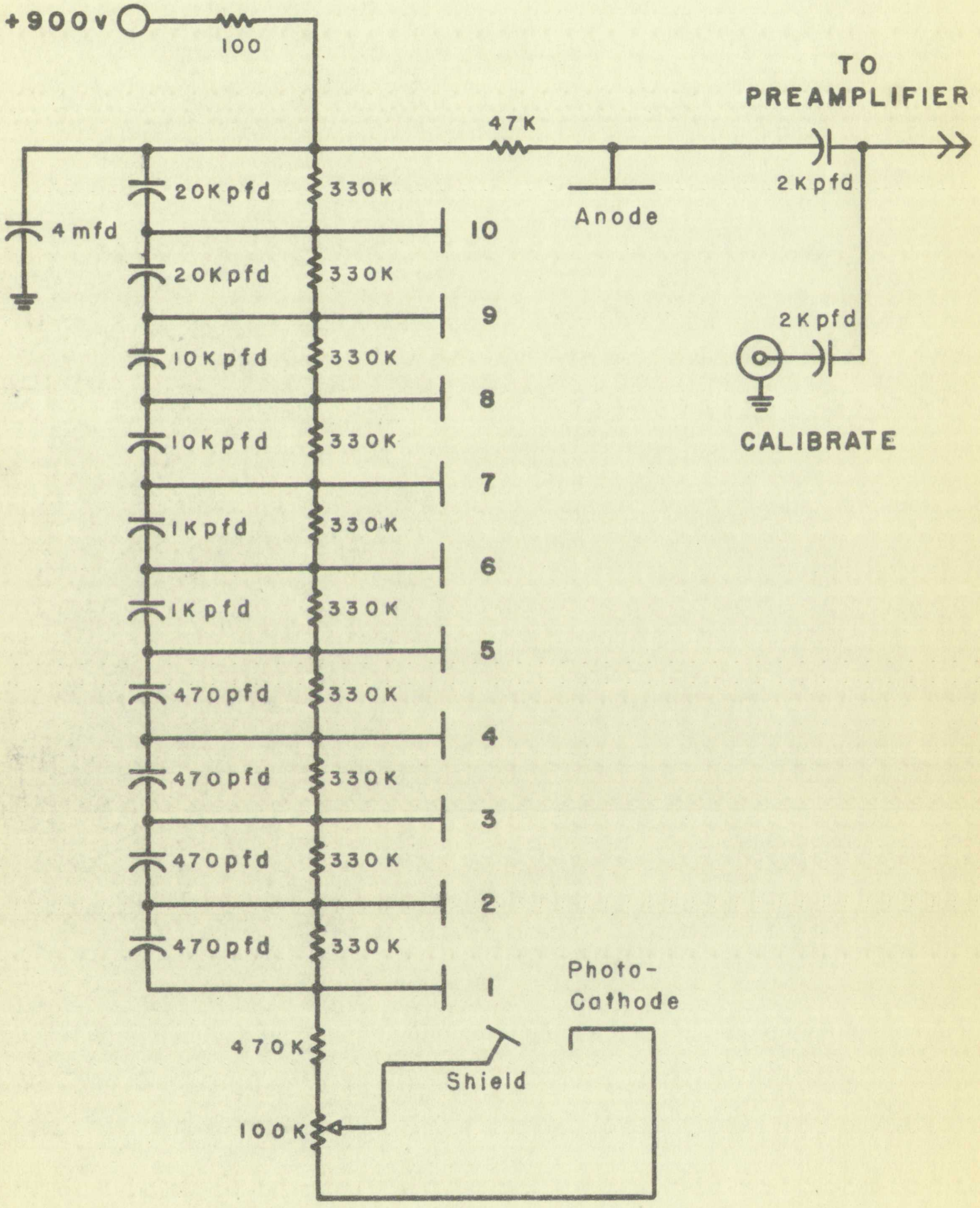


Fig. 4. Preamplifer Circuit

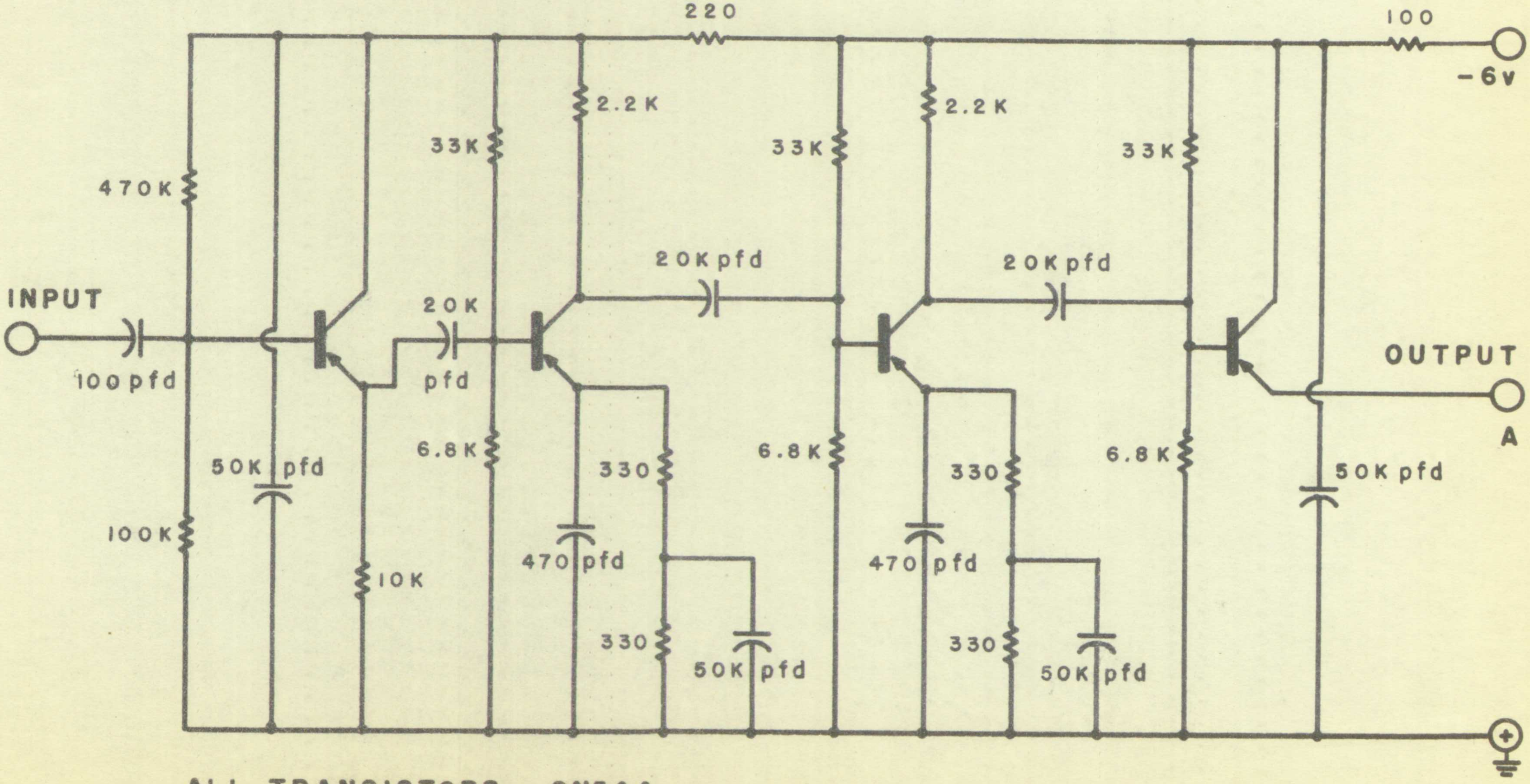


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Fig. 5. Linear Amplifier – Pulse Shaper Circuit

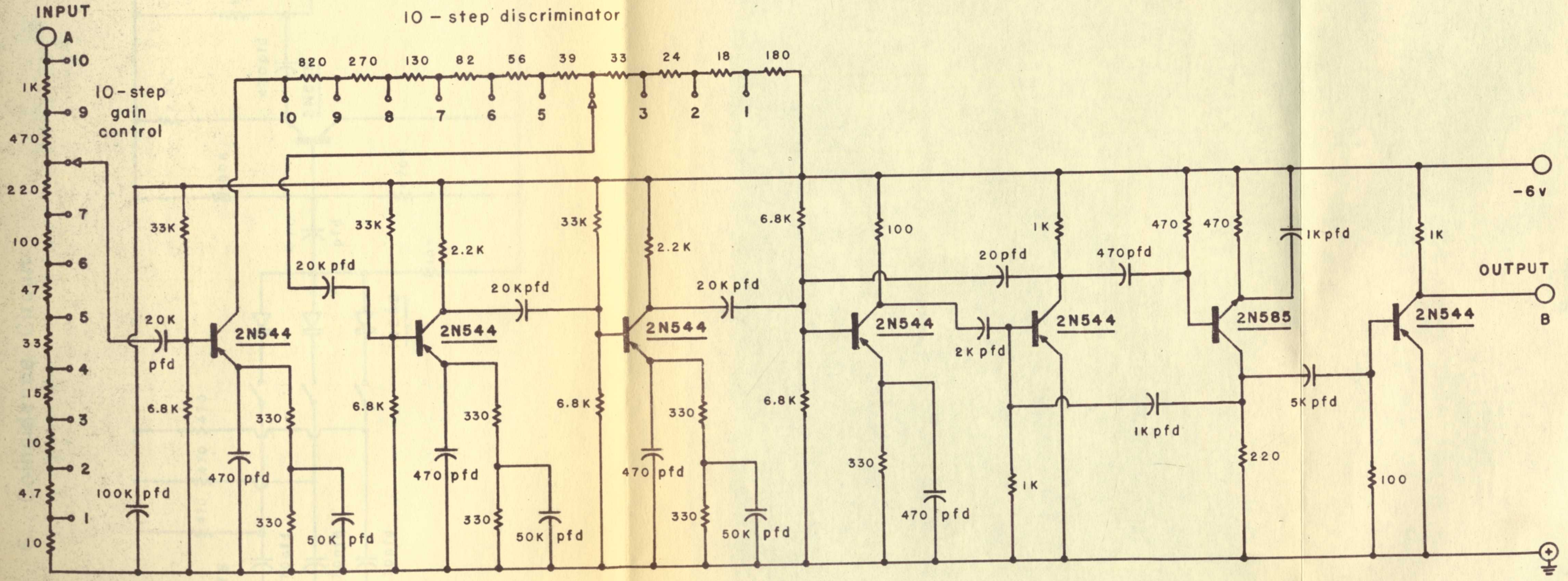
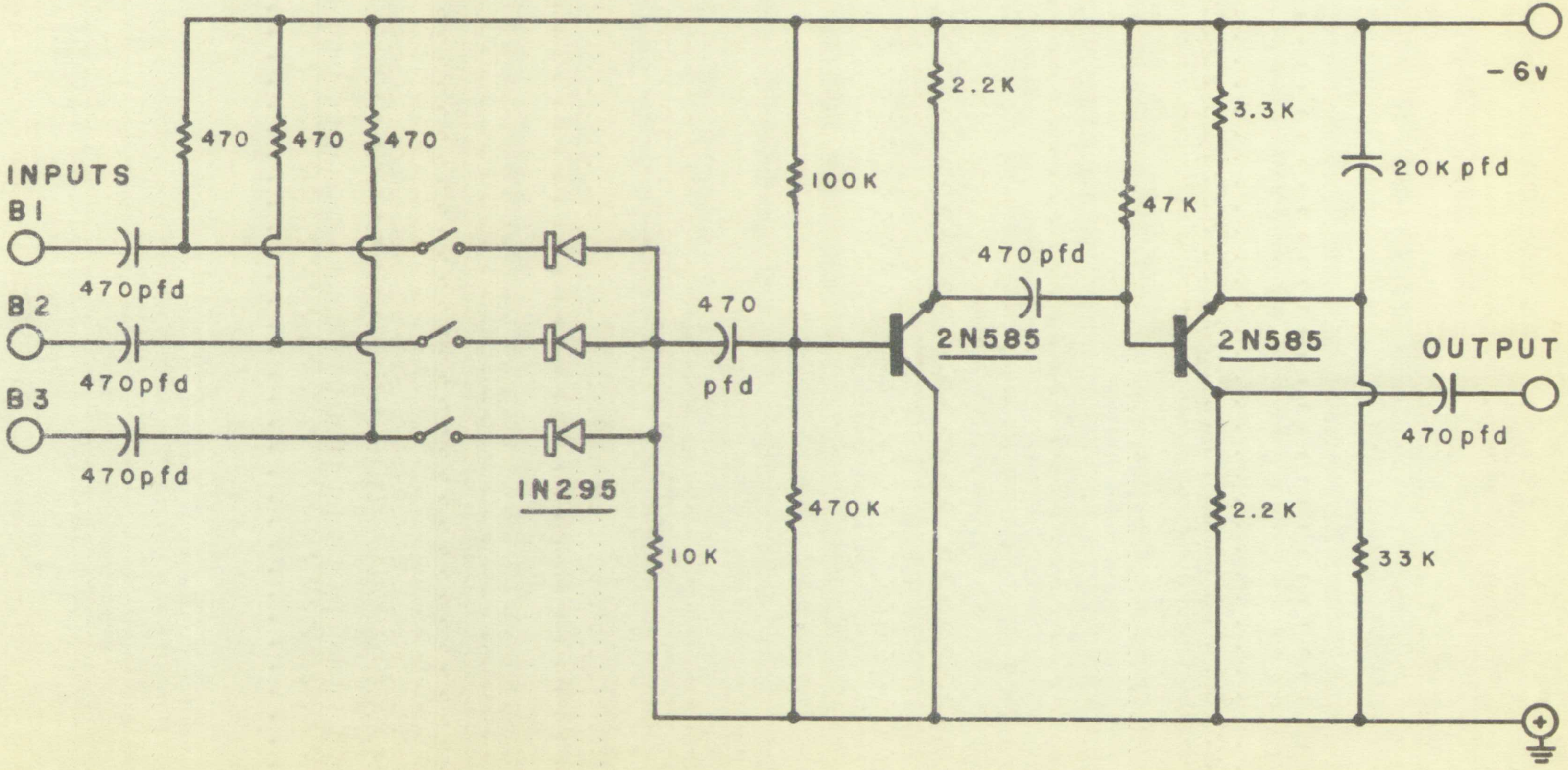


Fig. 6. Coincidence Circuit



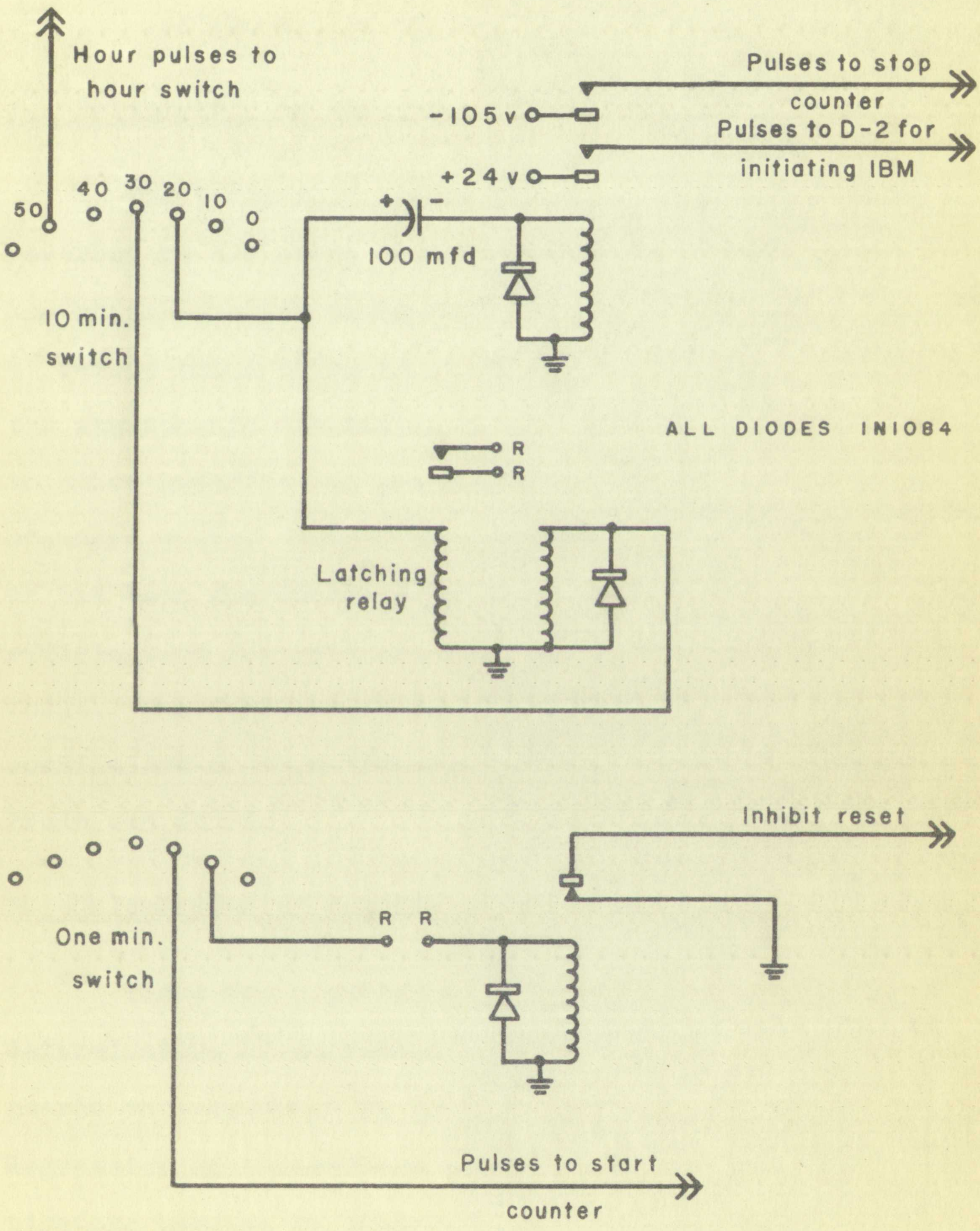
7060. The counter reads for 59 minutes of each solar hour and is then scanned and reset by relay controls operated by a solar clock (see Fig. 7). These controls have been adapted to the equipment in existence at the laboratory so that the date, the time and the number of counts per 59-minute period is recorded automatically on IBM cards.

Because of the necessity of correlating the intensity with the barometric pressure and atmospheric temperature in order to effect corrections for the variations of atmospheric origin, provision was made for the pressure and temperature to be recorded on the same punched cards as the time and intensity. A Microbarograph, Model No. 500029-1, Bendix Aviation Corp., Friez Instrument Div., Baltimore, Maryland, coupled by means of a servo system to a recording Veeder-Root indicator, was already in operation at the laboratory. A Model ML-77 Thermograph, Friez and Sons, Baltimore, Maryland, with similar recorder was put into operation to measure the air temperature outside of the laboratory. The thermograph was calibrated with respect to a Model No. 2115 Thermometer, (U. S. Weather Bureau), H. J. Green, Brooklyn, New York.

7060. The counts [illegible] hour and is then [illegible] operated by a solar [illegible] have been adapted to [illegible] laboratory so that the data, the high and low number of counts per 60-minute period [illegible] on IBM cards.

Because of the [illegible] tensity with the [illegible] temperature it [illegible] ations of atmospheric [illegible] the pressure and temperature [illegible] punched cards as the [illegible] graph, Model No. [illegible], [illegible] Instrument Div., Baltimore, Maryland, [illegible] of a servo system to a recording [illegible] was already in operation at the [illegible] ML-77 Thermograph, Friez and [illegible] with similar recorder was not [illegible] the air temperature outside [illegible] graph was [illegible] Thermometer, U. S. Gauge [illegible] lyn, New York.

Fig. 7. Counter Read-Out Control Circuit



CHAPTER III

DETERMINATION OF ATMOSPHERIC COEFFICIENTS

A. Calibration of Recording Equipment

The barometric pressure and air temperature are recorded on the punched cards in arbitrary units. Although for the immediate experiment it is not necessary to reduce these units to standard units, in order that the atmospheric correction coefficients could be related to other experiments, the equipment was calibrated for standard units. The calibration of the pressure recorder had been previously done at the laboratory and a coefficient of 160 pressure units per cm. of Hg had been found. The temperature recorder was calibrated and a coefficient of 35.6 temperature units per degree centigrade was found.

B. Calculation of Coefficients

There are a number of views with respect to the determination of corrections to the intensity for atmospheric variations as is indicated in the introduction. Regression equations have generally been used by investigators because of their simple form and ease of treat-

CHAPTER [illegible]

DETERMINATION OF ATMOSPHERIC CORRECTIONS

A. Calibration of Recording Equipment

The barometric pressure and [illegible] temperature were recorded on the punched cards in arbitrary units. Although for the immediate experiment it is not necessary to reduce these units to standard values, e. g., the fact that the atmospheric correction equations would be of interest to other experiments, the units were converted to standard units. The calibration of the pressure recorder had been previously done at the [illegible], and a coefficient of 160 pressure units per [illegible] was found. The temperature calibration was made and a coefficient of 35.6 temperature units per centigrade degree was found.

B. Calculation of Corrections

There are a number of [illegible] for the determination of corrections to the data for atmospheric variations and [illegible] the [illegible]. Regression equations were [illegible] have [illegible] by investigators because of their [illegible] ment by the method of least squares. Although a number of correlations have been done in the form indicated by Duperier when sufficient data from ballon flights were available, the work of Mathews and others has indicated that this treatment is not completely satisfactory, and thus no particular treatment of the atmospheric variations is generally accepted.

In the present case, the data have been corrected by a regression equation of the form:

$$R_c = R_i \left[1 - \bar{b}\,(p_i - \bar{p}) - \bar{c}\,(t_i - \bar{t}) \right],$$

where R_i is the number of counts per 59 minute period, p_i is the barometric pressure and t_i the ground level air temperature at the end of the period, $\bar{p}$ and $\bar{t}$ the respective mean pressure and temperature over the term of operation, $\bar{b}$ and $\bar{c}$ the respective means of the daily pressure and temperature coefficients which had been established by the method of least squares daily for a major portion of the term of operation, and R_c is the corrected intensity.

The apparatus was in operation from March 25, 1960 until May 18, 1960 for a total period of 55 days. The temperature recorder was put into operation on April 7, and the pressure and temperature coefficients determined for 38 days. Because of the variations due to solar activity, the deviations in the correction coefficients were larger than would be expected over a period of little solar activity, however, none of the deviations ment by the method of least squares. [illegible] of correlations have been done in this work instead [illegible] Duperier when sufficient [illegible] were available, the work of [illegible] shows [illegible] that this treatment is not justified [illegible] thus no particular [illegible] variations is [illegible].

In the [illegible] corrected by a regression equation of the form

$$T_c = N_i[1 - \beta(P_i - \bar{P}) - \gamma(T_i - \bar{T})]$$

where N_i is the number of [illegible], P_i is the barometric pressure and T_i [illegible] air temperature at [illegible] the respective mean pressure and [illegible] of operation; [illegible] pressure and [illegible] established by [illegible] a major portion of the [illegible] in the corrected intensities.

The barometric and air temperature [illegible] from March 1960 until [illegible]. The temperature [illegible] 7, and the [illegible] determined for 30 days. Because [illegible] solar activity, the [illegible] coefficients were [illegible] of little solar activity, [illegible] from the mean exceeded $4s_1$, where s_1 is the standard deviation of an individual datum calculation, and so all of the data have been retained in the calculation of the coefficients. This treatment resulted in the following coefficients:

$$\bar{b} = -(2.62 \pm 0.61)\%/\text{cm. Hg.}$$

$$\bar{c} = -(0.098 \pm 0.018)\%/\ ^{\circ}\text{C.}$$

CHAPTER IV

MEASUREMENTS OF VARIATION IN INTENSITY

A. Calculation of Energies of Detected Particles and Single Particle Calibration

As is mentioned in the introduction, the lower limit of the energies of the counted particles will be determined by the amount of absorber placed between the top and bottom tanks which are counted in coincidence. Since there is 8 in. of lead absorber in the telescope, if we assume an ionization loss of 2 Mev./gm./cm.^{2} the minimum energy of the particles will be approximately 450 Mev. The tank walls, solutions, supports, etc. will cause this value to be raised somewhat, but this can be taken as a lower limit of the energies with the chance coincidences negligible.

Electron showers are believed to have an average energy per electron of approximately 100 Mev. at their maximum development; and since their maximum development is attained considerably above the elevation of Albuquerque, it is very unlikely that many electrons are counted by the apparatus. Also it is very likely that the pi-mesons have decayed or suffered collisions by the time they reach this level of the atmosphere. Thus it can

be assumed that the particles counted by the telescope are, in the great majority, positive and negative mu-mesons with energies in excess of 450 Mev.

Each tank was individually calibrated for single particles.[27] The procedure was as follows: The gain of the amplifier was set for a rate of approximately 10,000 counts per minute. With this gain setting, the number of counts for 5 minute periods with different discriminator settings was recorded and the differences taken. The discriminators of all three amplifiers were then set at the values which corresponded to the maximum in the respective difference spectrums.

B. Intensity of Mu-Mesons at Albuquerque for the Period from March 25 to May 18, 1960

In Fig. 8 the mean intensity of mu-mesons for quarter-days is plotted for the period from March 25 to May 18, 1960. The values plotted represent those quarter-day periods for which four or more hours of data were available. The values for the days from March 25 to April 6 have been corrected for pressure only, while the remaining values have been corrected for both pressure and ground level air temperature. The Mean Belvoir Magnetic A-Index of the reports of the High Altitude Laboratory at Boulder, Colorado is also shown on the same graph. This index is calculated from the magnetic K-index and is indicative of variations in the earth's be assumed that the particles [illegible] are, in the great majority, [illegible] mesons with energies in excess of [illegible].

Each tank was [illegible] with [illegible] particles.^{27} The procedure was as follows: [illegible] the amplifier was set [illegible] minutes [illegible] counts per minute, [illegible] of counts for 5 minute [illegible] ator settings was [illegible]. The discriminators of all [illegible] were [illegible] at the values which [illegible] respective [illegible].

B. Intensity of [illegible] from March [illegible]

In Fig. 4 the mean [illegible] quarter-days is plotted for the [illegible] from March [illegible] to May 18, 1950. The [illegible] day periods for which [illegible] available. The [illegible] April 5 [illegible] the remaining values [illegible] for both [illegible] sure and ground level [illegible]. The mean [illegible] Magnetic K-index of the [illegible] oratory at Boulder, Colorado [illegible] graph. This index is calculated from the magnetic K-index and is indicative of variations in [illegible] magnetic field and in turn of solar activity.[28]

As has been indicated in the introduction, investigators have not been able to correlate the variations in mu-meson intensity with any particular characteristic of solar activity. It is evident from the graph that major decreases in meson intensity are somehow related with periods of high geomagnetic and solar activity.

The two highest values of the A-index occur 29 days apart. The onset times and minimums of the first two major decreases appear to be respectively 27 and 25 days apart. This would seem to indicate a 27-day recurrence tendency. The shift in the minimum may be due to the fact that the fall off in A-index values is sharper in the second case than the first.

The decreases associated with peaks in the values of the A-index seem to persist for some time after the periods of high A-index and have a period of slow recovery. The peak in the A-index on May 8 (solar day 129) appears to have further depressed the intensity before its complete recovery from the decrease due to the A-index peak on April 30 (solar day 121). A similar effect in lesser degree seems to occur with respect to the first two peaks. If the intensity decrease precedes the increase in A-index, it is not apparent from the graph.

The above results seem to favor a mechanism by which the earth enters a fairly well defined beam of magnetic field and [illegible] solar activity.

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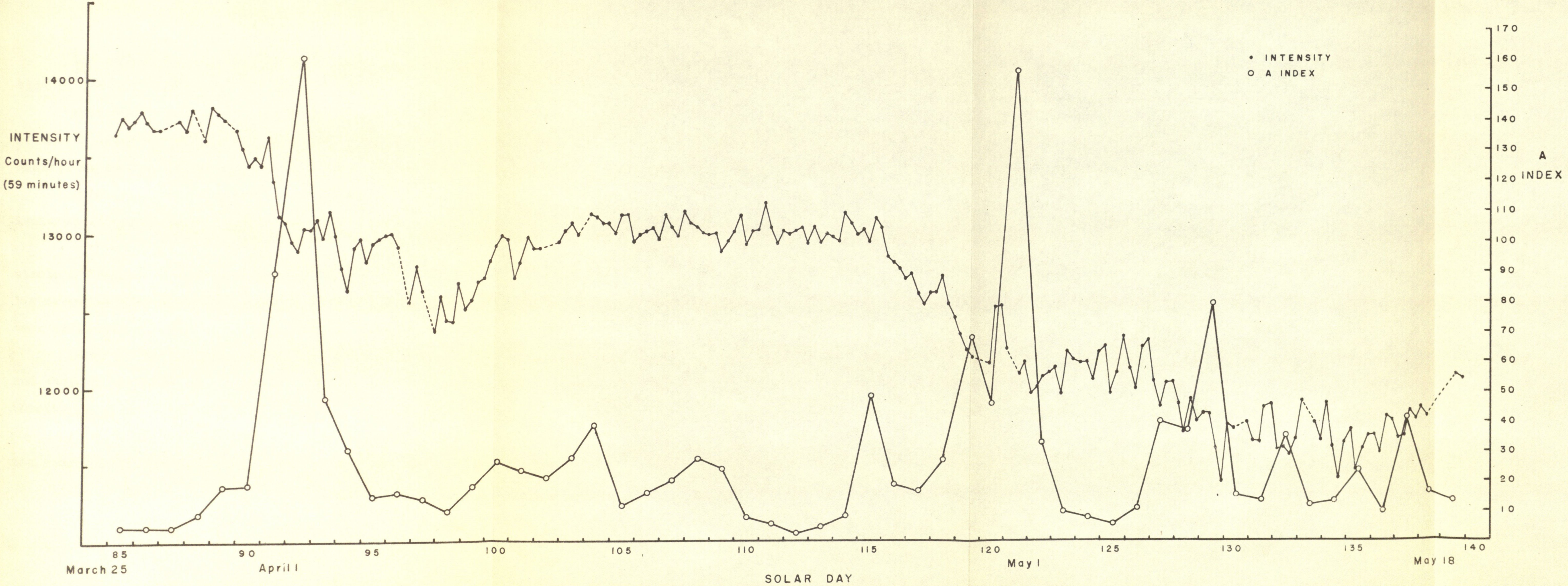
particles, as evidenced by the onset times in relation to the increase in A-index, but the effect of the beam on cosmic ray particles is somehow retained by the earth, as seems to be indicated by the slower recovery after the minimum in intensity. Also, the view seems to be supported that there is no simple relation between the effect of the beam on the earth's magnetic field and the effect on cosmic ray intensity.

Variations of smaller period are indicated, but little can be surmised from the graph, nor are these variations generally well understood.

Fig. 8. Plot of the Intensity of Mu-Mesons from March 25 to May 18, 1960



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Professor Victor [illegible] electronic circuits for the [illegible] lifier-pulse shaper and [illegible] been developed by him.

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