Time Variation of Cosmic Ray Intensity

by

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If the sun is a source of primary cosmic radiation then one will expect correlation between solar disturbances and cosmic ray intensity also variations with solar day, seasonal variations, and variations with solar day, seasonal variations, and variations with the eleven year cycle of increased sunspot activity.

In the work done here only solar disturbances effects have been studied. The period of study was from December 1960 to April 1961, except for the month of February of 1961 where no study was made due to instrument failure during that month.

Data about solar flares was gathered from two bulletins, the first issued by the Royal Netherlands Meteorological Institute and the Netherlands Postal and Telecommunications Services; the other was issued by the National Bureau of Standards in the U. S. A.

Unfortunately, during the period of study no major effects due to solar disturbances were recorded here. This is also in agreement with observation recorded in the places issuing the above bulletins. In as far as the author knows this is in agreement with observations taken at other centers in the world.

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done is presented. Prior to that a brief account about cosmic radiation is given of such a nature to make one able to understand the phenomena being studied.

The author wishes to thank Dr. Frans Bruin, his thesis advisor for his help in this work. He also wishes to thank the Ford Foundation for the fellowship which made his graduate study possible.

ABSTRACT

The time variation of the intensity of cosmic rays is studied continuously by observing the neutron component of the secondary rays.

Basically, the neutrons are detected by slowing them in paraffin and then capturing them in a BF_3 gas counter.

It was hoped that a study of the time variation of cosmic rays during solar flares and magnetic storms will lead to a better understanding about the origin of cosmic rays. Unfortunately, no significant effects were recorded during the period of study. This was in agreement with observations recorded at other centers in the world.

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SECTION (1)

COSMIC RADIATION

I. Introduction

About fifty years ago, a type of radiation was discovered that falls continuously on the earth from outer space. This radiation is now called cosmic radiation. Every second nearly a billion billion cosmic ray particles plunge into our atmosphere heading towards the earth. During their passage in the atmosphere the cosmic ray particles interact with the nuclei of the air and secondary particles are produced.

There is enough evidence now that primary radiation consists of positively charged particles distributed in space with a high degree of isotropy and with a continuous energy spectrum up to at least 10^{18} ev.

II. Detection of Cosmic Rays on the earth

The cosmic radiation reaching the earth is modified by the earth itself through both its magnetic field and the atmosphere. Hence in order to reconstruct the primary flux one has to evaluate both these effects.

(a) Geomagnetic effects

The magnetic field of the earth resembles to a close approximation that of a dipole of strength $M = 8.1 \times 10^{25}$ gauss-cm^3 located 342 km from the earth's geometric center, its axis intersecting the earth's surface at 80.1° N 82.7° W and 76.3° S 121.2° E.

The magnetic influence of the earth's field extends to about seven times the earth's radius. While the top of the atmosphere can be considered not more than 60 km above the surface of the earth. Hence if the cosmic ray particles are electrically charged then they would be influenced by the magnetic field of the earth, long before they plunge into the atmosphere. Such an influence has been observed (1) which shows beyond any doubt that cosmic rays are charged particles.

The motion of a charged particle in the magnetic field of the earth is a complicated problem. It has been tackled in an extensive manner by Stormer (2) Lemaitre and Vallarta (3).

A brief summary of their calculations shows that particles need a certain minimum momentum to arrive at a certain point on the earth in a given direction (4). For relativistic particles with total energy much greater than their rest energy this minimum momentum for the particles to arrive in the vertical direction at a magnetic latitude θ is approximately given by:

$$P_{min} = 14.8 \cos^4 \theta \quad \text{Bev/c} \tag{1}$$

For positive charges arriving at magnetic latitude θ and in the east west plane and at an angle ϕ from the zenith this minimum momentum is given by:

$$P_{west} = 59.3 \frac{\cos^4 \theta}{\left[1 + (1 + \sin \phi \cos^3 \theta)^{1/2}\right]^2} \text{Bev/c} \tag{2}$$

$$P_{east} = 59.3 \frac{\cos^4 \theta}{\left[1 + (1 - \sin \phi \cos^3 \theta)^{1/2}\right]^2} \text{Bev/c} \tag{3}$$

For negative charges the left sides of equations (2) and (3) should be interchanged. For any values of θ and ϕ equations (2) and (3) predicts that it is easier for a slow positive primary to come from the west than from the east. The reverse is true for a negative charge.

The intensities of cosmic rays were measured in the eastward and westward direction at many places (5). The results showed that the intensity of particles coming from the west is greater than the intensity of particles coming from the east. Thus proving the fact that cosmic rays are predominantly of positive charge. Careful analysis of the results (5) also showed that these positive charges were predominantly protons.

From equation (1) one would expect a steady increase in the intensity of cosmic rays - above the atmosphere - as one goes from the equator and towards either the magnetic north pole or the magnetic south pole. Actually such an increase is found up to magnetic latitudes of about 58° North and South of the magnetic equator as is shown in Figure 1. After that the intensity remains approximately constant up to the magnetic poles. This shows that primary particles with momentum below the cut off momentum at 58° do not reach the top of the atmosphere.

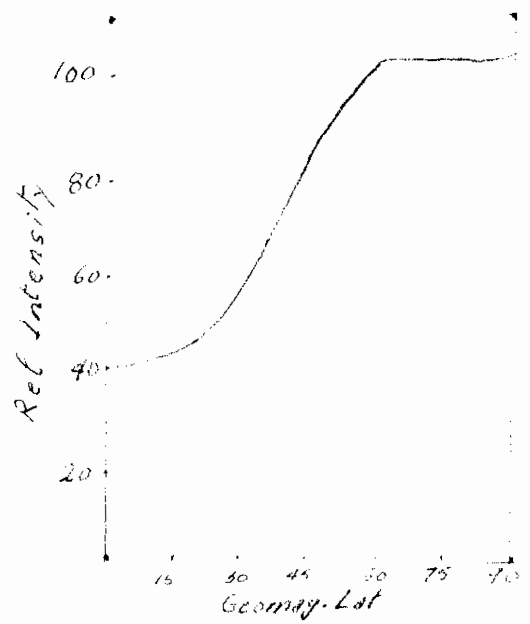

Figure 1. The Geomagnetic Latitude Effect as Measured Chiefly by Nehar and co-workers. (The South Latitude Effect Resembles the North Latitude Effect).

The absence of the low energy particles from the primary radiation has been explained by J'anossy (4) as being due to the magnetic field of the sun this would deflect such low energy particles and keep them from reaching the earth.

Another explanation of the above latitude effect could be due to an inherent change in the form of the primary spectrum due to the mechanism of generation or propogation of cosmic rays.

Up till now not enough data is collected to decide on the exact reason of this latitude effect.

(b) Atmospheric effects

Before entering the atmosphere the energy of the cosmic rays is carried by an isotropic and homogeneous stream of particles with varying kinetic energies. The earth's magnetic field acts on these particles as a momentum selector. The intensity of the primaries decreases as their energy increases and falls off to very low values at energies of the order of 10^{18} e . The incident radiation is composed of atomic nuclei consisting of about 90 per cent protons, about 10 per cent alpha particles (6). and about 1/2 per cent nuclei of heavier elements.

As these primary cosmic particles descend into the atmosphere they interact with the nuclei of the air and what one detects at sea level is only the secondary effects of the primary rays. These particles during their entrance in the atmosphere will loose some energy by ionization but only those having a fairly low energy might be stopped by this process. Almost all the incident particles will suffer nuclear collisions with nitrogen and oxygen nuclei in the upper atmosphere. As a result of this interaction which we shall designate by (A) the energy of the primary particle will now be shared between a number of secondaries which can be grouped as follows:

(1) High energy nuclear active component (fragments of nuclei nucleons antinucleons mesons) - This component will induce more reactions of the type A.

(2) Low energy nuclear active component (low energy nucleons and mesons) - This gives rise reactions of type B where no mesons are created but only slow nucleons are produced.

In both the upper two cases most of the secondaries will be absorbed before reaching the surface of the earth, slow protons being stopped by ionization and neutrons by capture in nitrogen.

(3) Neutral π mesons - These decays immediately ($\tau \leq 10^{-14}$ sec) into two photons which by creation of electron positron pairs initiate an electron photon cascade. The number of particles continues to increase by multiplication until the energy of the electrons has degraded to a point where energy loss by ionization dominates energy loss by bremsstrahlung and until the photon energies have been reduced to an extent where compton scattering and photoelectric absorption dominates pair production.

(4) Charged π mesons - These decay with a life time of $\approx 2.5 \times 10^{-8}$ sec into a μ meson and a nutrino. In the rarefied parts of the atmosphere the π meson will decay before having any chance to suffer a nuclear collision. But for high energies of π meson (≥ 50 Bev) its life time will increase enough due to relativistic effects to make nuclear collisions quite probable.

The μ meson passes almost freely through matter. Losses due to bremsstrahlung and pair production are not important for energies below 100 mev. Losses due to ionization predominates. A μ meson decays with a life time of $\approx 2.1 \times 10^{-6}$ sec into an electron and two nutrinos.

Because of time dilation due to relativistic effects μ mesons with energies greater than a few Bev have a chance to reach the earth before decaying. At sea level μ mesons constitute about 80 per cent and electrons formed by decay and ionization processes about 20 per cent of the particles incident on the earth surface.

Below is a figure showing the component of a primary cosmic shower.

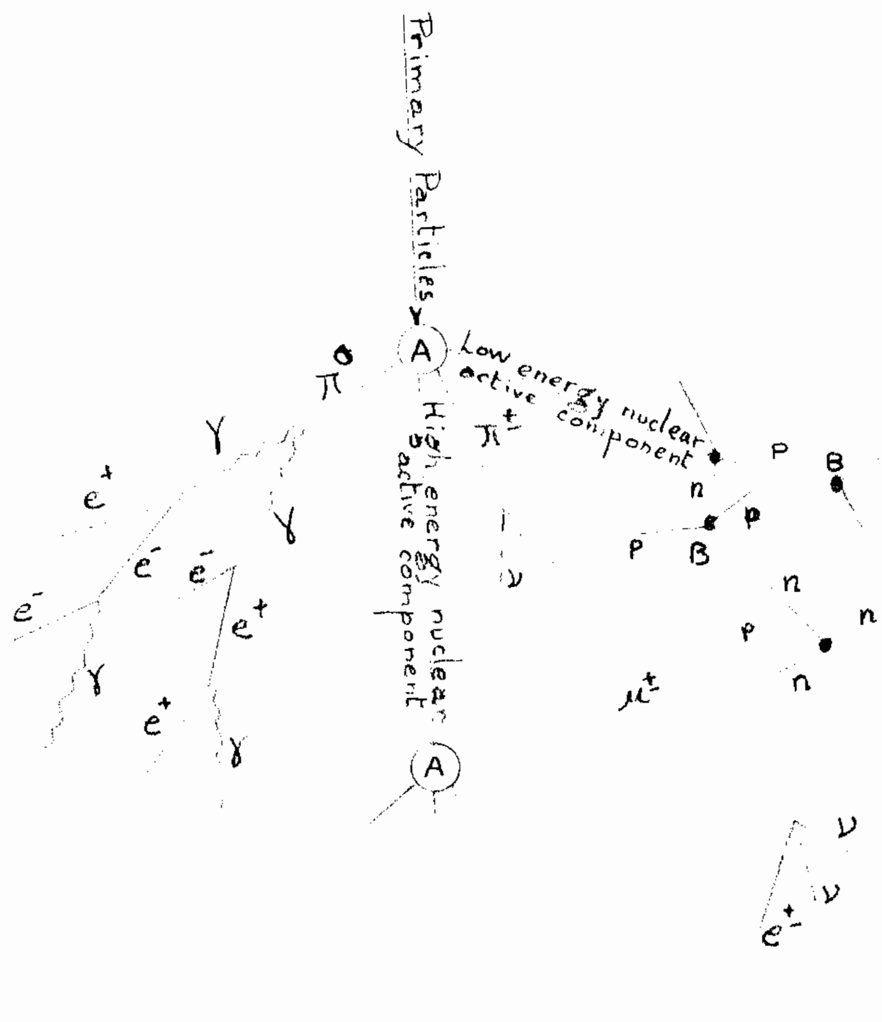

Figure 2. Components of primary cosmic ray shower.

SECTION (2)

TIME VARIATION OF COSMIC RAY INTENSITY

I. Qualitative treatment

On the average the flux of cosmic rays is constant in intensity and composition and at least up to 10^{18} ev highly isotropic in the space surrounding the earth.

However time variations do occur: the variations that occur due to the sun are called solar variations; variations that occur in relation to the celestial sphere are called sidereal variations. Up till now no definite evidence exists for variations with a recurrence related to sidereal time.

On the other hand solar variations can be grouped as either periodic or non-periodic.

(1) Periodic fluctuations. The fluctuations are of the order of one per cent of the average intensity. The periods of recurrence are:

- (a) Diurnal
- (b) 27 day (due to rotation of the sun around its axis)
- (c) 11 years (cycles of solar activity)

(2) Non periodic fluctuations:

- (a) Fluctuations associated with solar flares.
- (b) Fluctuations associated with magnetic storms of solar origin.

In the work done here only fluctuations associated with solar flares were studied.

<u>Measurement of the time variations:</u> Because time-variation studies take a long time, they are easiest done now-a-days at least on the surface of the earth.

In such cases, changing meteorological conditions will affect the cosmic rays intensity as measured on the surface of the earth. Hence for a correct interpretation of the time fluctuations, one has to correct for meteorological effects.

This correction will of course depend upon the properties of the particles one is detecting; for every particle will behave differently with respect to changing atmospheric conditions, such as pressure and temperature.

Before 1953, most detectors for measuring time fluctuations were charged particle detectors. At sea level and moderate heights, these charged particle detectors, respond to μ mesons which were produced with sufficient energy to penetrate the atmosphere (energies $\geq$ Bev) and after correction for atmospheric effects, indicate intensity variations in the primary component of ten to twenty times that energy.

In 1952, Simpson, Fonger and Treiman (7) introduced detectors that measure the local neutron production, as indicators for primary intensity variations. The mechanism of the local production will be discussed in the third section.

In the work undertaken here, time fluctuation are measured using the method of Simpson, et al (7).

Neutron detectors have various advantages over charged particle detectors of the various meteorological variables, only pressure affects the local neutron production. The pressure coefficient under 600 gn/cm^2 of atmosphere is about 9.4 per cent per cm Hg (8).

Another major advantage is that the neutron detector responds mainly to the low energy, primary component, which shows much larger time variations than the high energy component (8).

II. Analytic Treatment*

In general - after correction for meteorological effects - variations of cosmic ray intensity as measured on the surface of the earth can be due to either changes in the primary spectrum of cosmic rays or to changes in the cutoff momentum values at the earth, because of certain terrestial magnetic perturbations. Of course the variations can be due to both of the above reasons. In what follows, the general way is shown for deciding on the reason of the variation. First, one defines few terms:

(a) Specific yield of neutrons S_Z (N, X) gives the observed time averaged counting rate of neutrons at a depth X in the atmosphere arising from a unit flux of vertically incident primary particles of charge Z and momentum to charge ratio (magnetic rigidity) $P/Z = N$. It has to be mentioned that according to Vallartas work, the trajectories of a particle are determined uniquely by its magnetic rigidity N.

(b) The differential spectrum for primary particles of charge is given by $j_Z(N,t)$; j_Z dN gives the number of particles of charge Z having energies such that their magnetic rigidities lie between N and dN at time t.

Now for any magnetic latitude there is a certain cutoff value for the momentum of particles arriving from a given direction. Since magnetic rigidity and momentum are connected through the expression $P/Z = N$, one will have a magnetic cutoff value for each magnetic latitude. For particles arriving at magnetic latitude λ from a zenith angle θ and azimuthal angle ϕ, the cutoff magnetic rigidity is denoted by $N(\lambda, \theta, \phi)$. Hence the total counting rate $R(\lambda, X, t)$ at time t for a neutron detector placed at magnetic latitude λ and depth X is given by

*This treatment is based completely on the work of Simpson et al. (Reference 7).

$$R(\lambda, X, t) = \sum_Z \int_0^{2\pi} d\phi \int_0^{\frac{\pi}{2}} \sin\theta d\theta \int_{N(\theta,\phi,\lambda)}^{\infty} S_Z\left(N, \frac{X}{\cos\theta}\right) j_Z(N,t) dN$$

Also the counting rate per unit solid angle in the vertical direction is given by $R_v(\lambda, X, t)$ where

$$R_v(\lambda, X, t) = \sum_Z \int_{N_v(\lambda)}^{\infty} S_Z(N, X)\, j_Z(N, t)\, dN$$

and $N_v(\lambda)$ is the magnetic cutoff rigidity for latitude in the vertical direction.

The relation between R_v and R at large atmospheric depths is given by the cross transformation.

$$2\pi R_v = R\left(1 + \frac{X}{L}\right)$$

where $$1/L = -R^{-1} (dR/dX)$$

differentiating equation (2) one obtains

$$\frac{dR_v}{d\lambda} = - \sum_Z S_Z(N_v, X)\, j_Z(N_v)\, (dN_v/d\lambda)$$

(a) Variation of primary cosmic radiation intensity:

It has been demonstrated that a change in the value of $dR_v/d\lambda$ is due to a change in the primary flux having rigidity equal to the cutoff value at λ. It has also been demonstrated that above $\lambda = 43°$ any change in $dR_v/d\lambda$ is due mostly to a change in the proton part of the primary spectrum and not as much to the other heavier particle.

(b) Variations of magnetic cutoff rigidities:

Concerning terrestial magnetic perturbations, one can state that irrespective of the reason for the flattening of the neutron latitude curve above the knee 52° to 56°, no magnetic perturbations can account for an increase or decrease of neutron intensity above the knee. The reason is that, a decrease in magnetic rigidities due to magnetic perturbations should allow lower energies to reach all latitudes, but the presence of the knee itself indicates that either there are no low energy particles in the primary radiation, or that their specific yield for neutrons is very small. Which ever the case be, it is clear now that no increase above the knee could be attributed to a decrease of magnetic rigidities.

Above the knee the neutron intensity is low enough and so an increase in magnetic rigidity cannot influence a change above the knee.

However, a change in the magnetic rigidities will of course effect the neutron intensity as measured below the knee.

In order to make analysis of results as shown in this section, one needs standardized data from many locations of different magnetic latitude.

The work undertaken here is a representative of one such location, and the only effects measured are those due to non-periodic solar disturbances.

SECTION (3)

THE LOCAL NEUTRON PRODUCTION

The neutrons to be measured are detected by BF_3 proportional counters. These counters have a high cross section for counting only slow neutron. Hence, one has to slow the neutrons before being efficiently detected by the counters. This is done by using paraffin as a moderator, but then difficulties might arise during severe atmospheric changes such as precipitation and snow formation.

Another problem in neutron counting is that the counting rate for a given quantity of BF_3 gas is relatively low. To get a higher rate one requires that the neutrons detected originate locally in condensed material by a star mechanism due to secondary particles. It will be shown later that the nucleonic component of the secondary particles is the most effective component for this mechanism. The process outlined above is defined as "local neutron production." The neutron production in elements is a function of the atomic weight. The average number of neutron produced locally due to a secondary particle is called the multiplicity of the element; for lead at sea level and moderate heights this multiplicity is approximately equal to 8 (9). It was found experimentally (7) that 5 cm is the optimum value for lead surrounding the detectors so as to give the maximum counting rate.

The local production of neutrons in the lead by star mechanism is due to the nucleonic component of secondary particles and the meson component, (see figure below).

Since the lifetime of nucleonic component is long, one will not expect any temperature effect for local neutron production due to the nucleonic component. But for the mesonic component where life time is short, an effect is expected. However, it has been demonstrated by Simpson et al. (7) that the local neutron production due to mesons is small enough so that temperature change can be neglected.

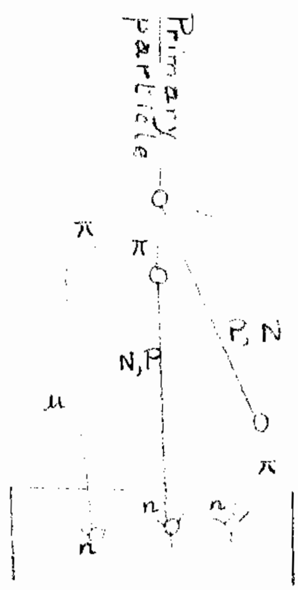

Figure 3. Star Production of Neutrons.

The neutrons detected respond strongly to atmospheric changes and an exponential absorption law holds. The coefficient of absorption at sea level and moderate heights is about -0.96 per cent per mm Hg (8).

SECTION (4)

DESCRIPTION OF THE APPARATUS AND INSTRUMENTS

I. The Pile

The geometry of the pile is divided into two sections A, B, each having three proportional counters. This gives a check on the performance of any section.

A diagram of the pile cross section shows in Figure 4. Paraffin is placed over the lead and on the sides to reduce neutron intensity outside the pile.

In Figure 5 the amount of lead used is indicated. Notice that for clarity, no paraffin is shown on the top of the top layer of lead.

Figure 6 indicates the details of a single counter moderation element. In the middle of the top layer of paraffin is formed a hole of sufficient size to accommodate a neutron source for checking purposes.

The total amount of paraffin contained in the pile is about 700 kgm. The total amount of lead is about 1250 kgm.

II. The Detection System

Each section of the pile consists of three counters each connected in parallel to an amplifier through an intermediate stage preamplification.

It should be mentioned that the output pulses from the BF_3 counters is in the millivolt range. Hence it is necessary to amplify the pulses and separate them from the much smaller beta and lethium recoil pulse before scaling the pulses for mechanical registration. Pulses from the amplifier output are selected by a discriminator which also provides the correct pulse shape for the scaler. The integral count is recorded by a register which is photographed along with a sensitive barometer and a chronometer every 15 minutes. Figure 7 is a sample of a picture taken by the camera. Figure 8 is a picture of the movie camera and its automatic mechanism which triggers every 15 minutes.

The scaler pulses also operate a count rate meter whose output is fed into a chart recorder. In what follows is described the basic characteristics of the different components of the detection system.

III. Proportional counters

BF_3 gas counters enriched with B^{10} isotope were used for detecting the neutrons. Their operation depend upon the capture of neutrons by B^{10} nuclei followed by splitting of the resulting nucleus according to the following equation:

$$_5B^{10} + {}_0n^1 \longrightarrow {}_5B^{11} \longrightarrow {}_3Li^7 + {}_2He^4$$

The Li and He (α particles) ions fly apart with considerable energy and produce intense ionization. The voltage across the counters is adjusted so as to operate in the proportional region and at a far distance from the Geiger region so as to detect neutrons even in the presence of rays.

The cross section for the capturing process is only large for thermal neutrons. This is why paraffin is used as a moderator in the pile.

The counter tubes are manufactured by Wood Counter Laboratory U. S. A. They have the following specifications:

(1) Gas: Pure BF_3 enriched in B^{10} isotope.

Pressure = 45 cm Hg.

(2) Dimensions: Length = 34 in.

Diameter = 1.5 in.

Center Wire Diameter = 0.001 in.

(3) Background: Normal < 1 c/min.

Cadmium surrounding counter < 1.5 c/min.

(4) Operating range: Plateau 1750 - 1950 volts

Operating Voltage 1800 volts

IV. Electronic and Electrical Equipment

A block diagram of the various electronic and electrical instruments used is shown in Figure 9. A and B refer to the right and left respective sections of the pile. Following are the basic specifications of the instruments:

(a) Regulated Power Supply: It is a PANAX EQUIPMENT Power Unit Type 3000. This unit covers the ranges 0-3000 volts and regulates to ±10 volts at 2000 volts over a power line input range of 90-130 volts.

(b) The scaler and discriminator are housed in one case PANAX EQUIPMENT Counting Equipment Type 100S. An arbitrary input pulse threshold of 1.0 millivolt from the proportional counters was fixed. The discriminator was adjusted to such an input by means of a pulse generator.

The scaler uses a scale of 10 circuit. Its outpue is fed into a mechanical counter on the photo panel.

The output of the scaler on the right is also fed into a count rate meter which gives directly the counts per minute. The output of the meter is fed directly into a chart recorder.

The preamplifier and amplifier are home built. Their circuit diagrams are shown in Figures 10 and 11 respectively.

V. Test Equipment

(1) A 2 milligram mixed Ra-Be source was used frequently to test the operation of the pile. The source produces neutron by the nuclear interaction of beryllium on the alpha particles formed from the decay of radium according to the equation

$$Be^{9} + He^{4} \longrightarrow C^{12} + n^{1}$$

The ratio of the counting rates from the A and B sections of the pile should remain constant in time.

Also during normal operation the ratio of counting rate from the A and B sections should remain constant in time.

The source is a product of the Atomic Energy of Canada Lt. Its specification are as follows:

Nominal value	2 mgs
Actual value	2.1 mgs
Type of source	Ra-Be Neutron source with ratio 1:13
Container	Monel double sealed Radum 5 mgm capsule

Dimensions	Inner	Outer sheath
Outside Diameter	7.9 mm	12.6 mm
Outside Length	9.0 mm	14.7 mm
Wall = Base	2 mm	2 mm

(2) The scaler and discriminator are tested occasionally by means of a pulser 50 pulses/sec at a height of 1.00 milli volt.

(3) Occasional visual tests are made on the output of the scales by means of an oscilloscope. Any superfluous pulse can be easily noticed.

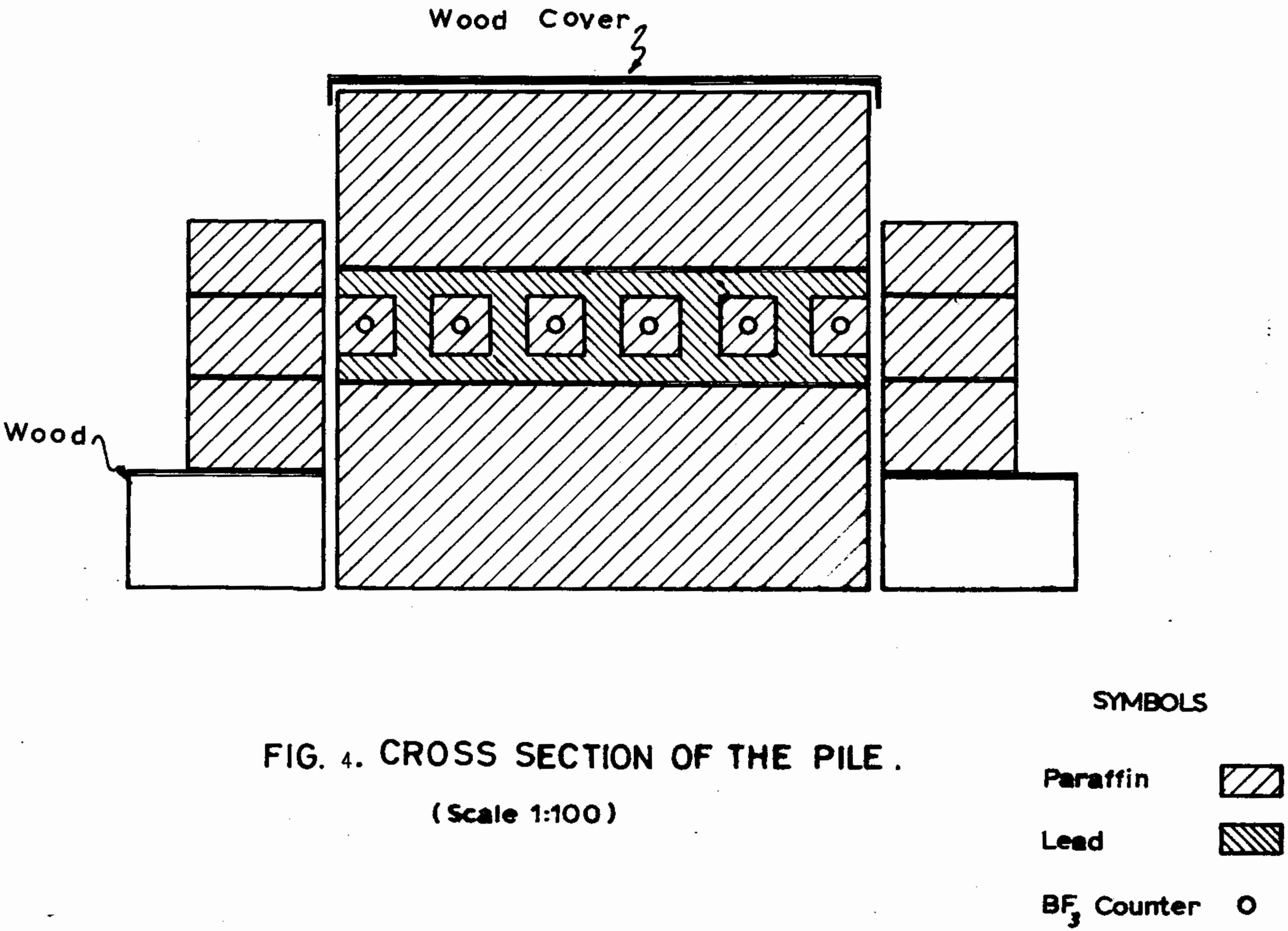

FIG. 4. CROSS SECTION OF THE PILE.

(Scale 1:100)

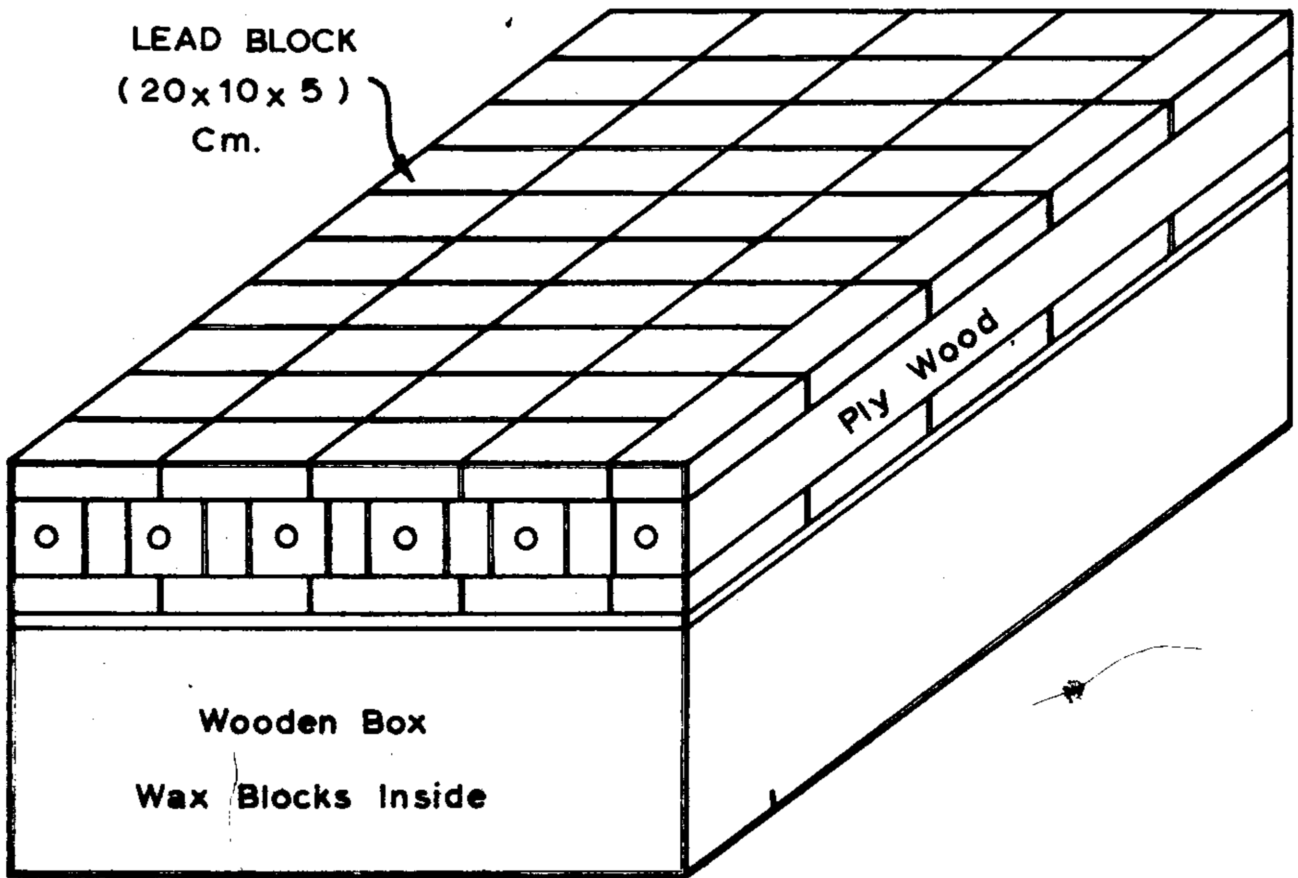

FIG. 5. DIAGRAM SHOWING LEAD USES.

(Scale 1:100)

LEAD BLOCKS USED	
Bottom layer	45
Spacers	25
Top layer	45
TOTAL	115

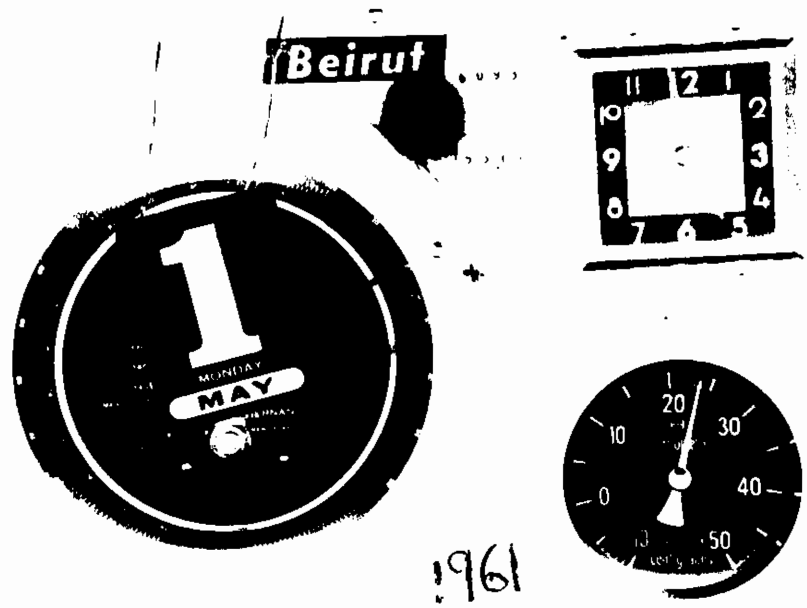

FIG. 7. SAMPLE PICTURE OF INFORMATION GATHERED BY FILM

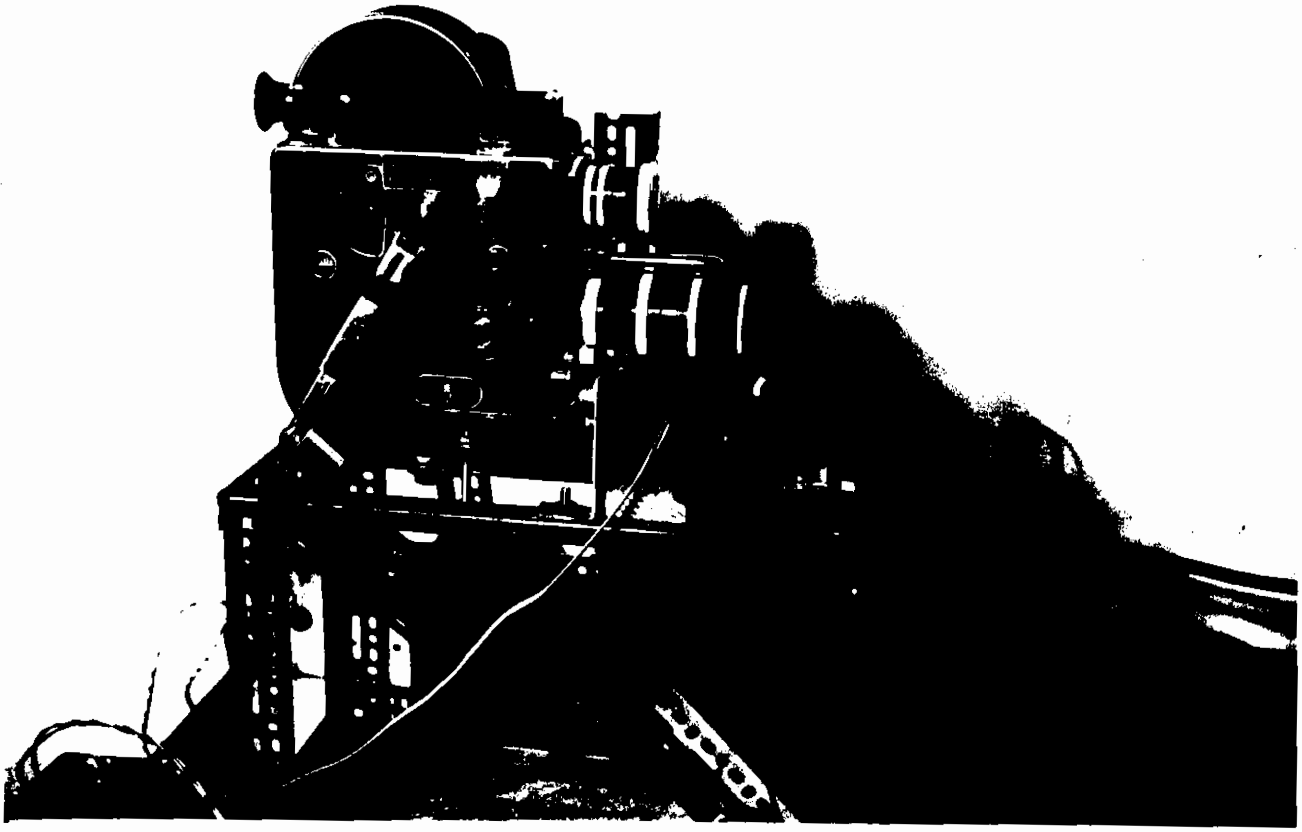

FIG. 8. PICTURE OF MOVIE CAMERA WITH ITS TRIGGERING MECHANISM

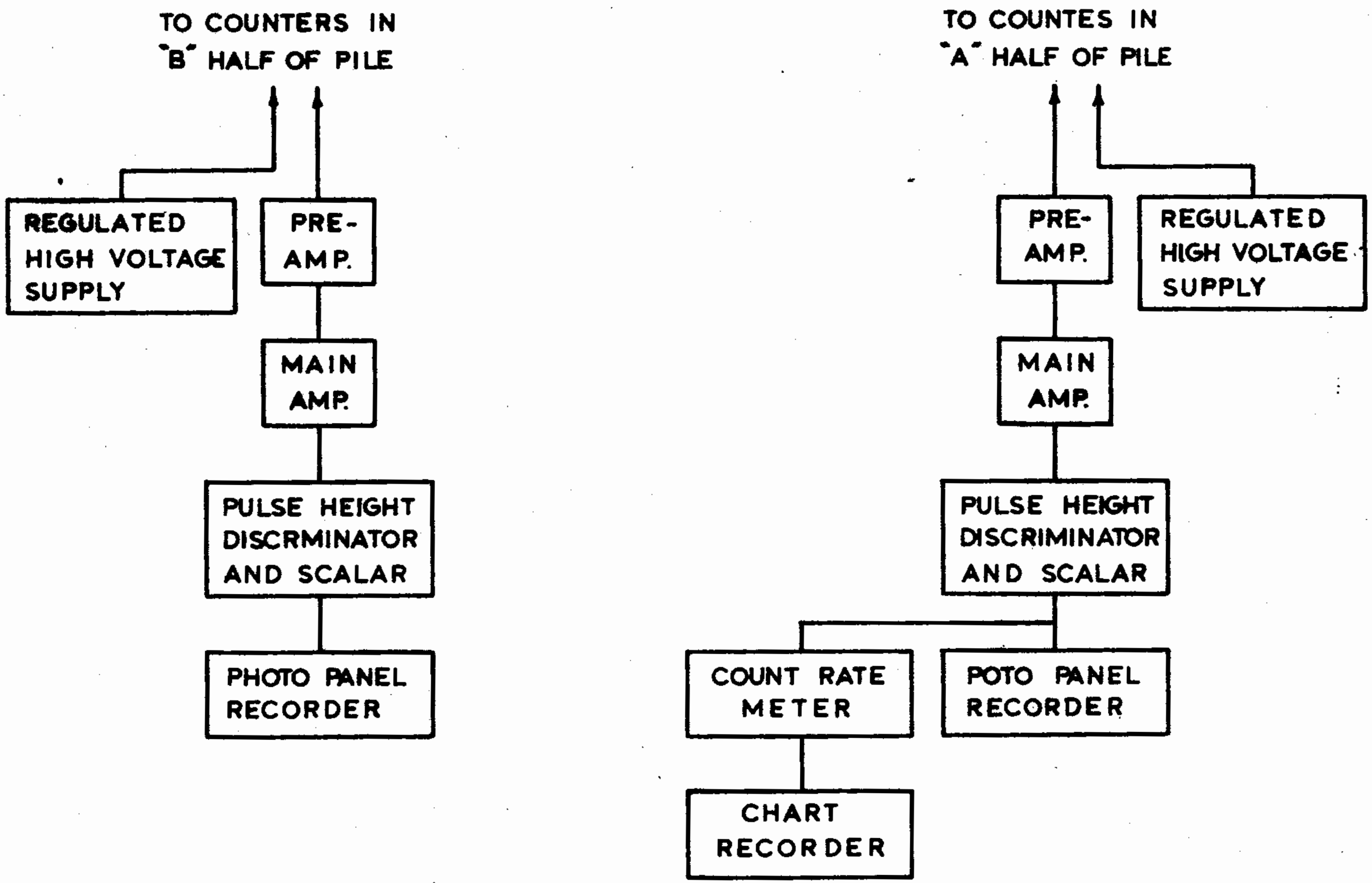

FIG. 9. BLOCK DIAGRAM OF ELECTRIC CIRCUITS USED

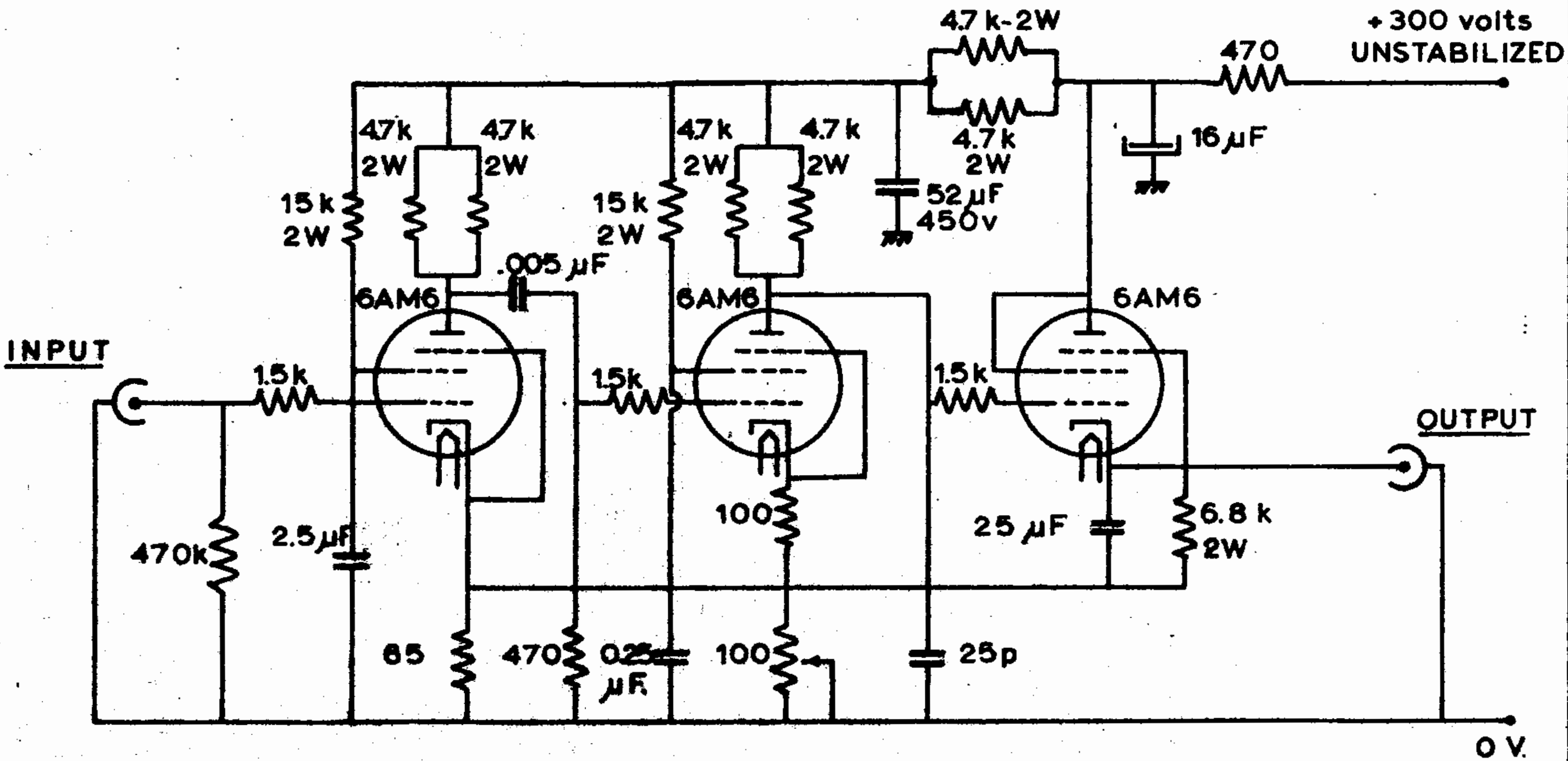

FIG.10. PRE - AMPLIFIER

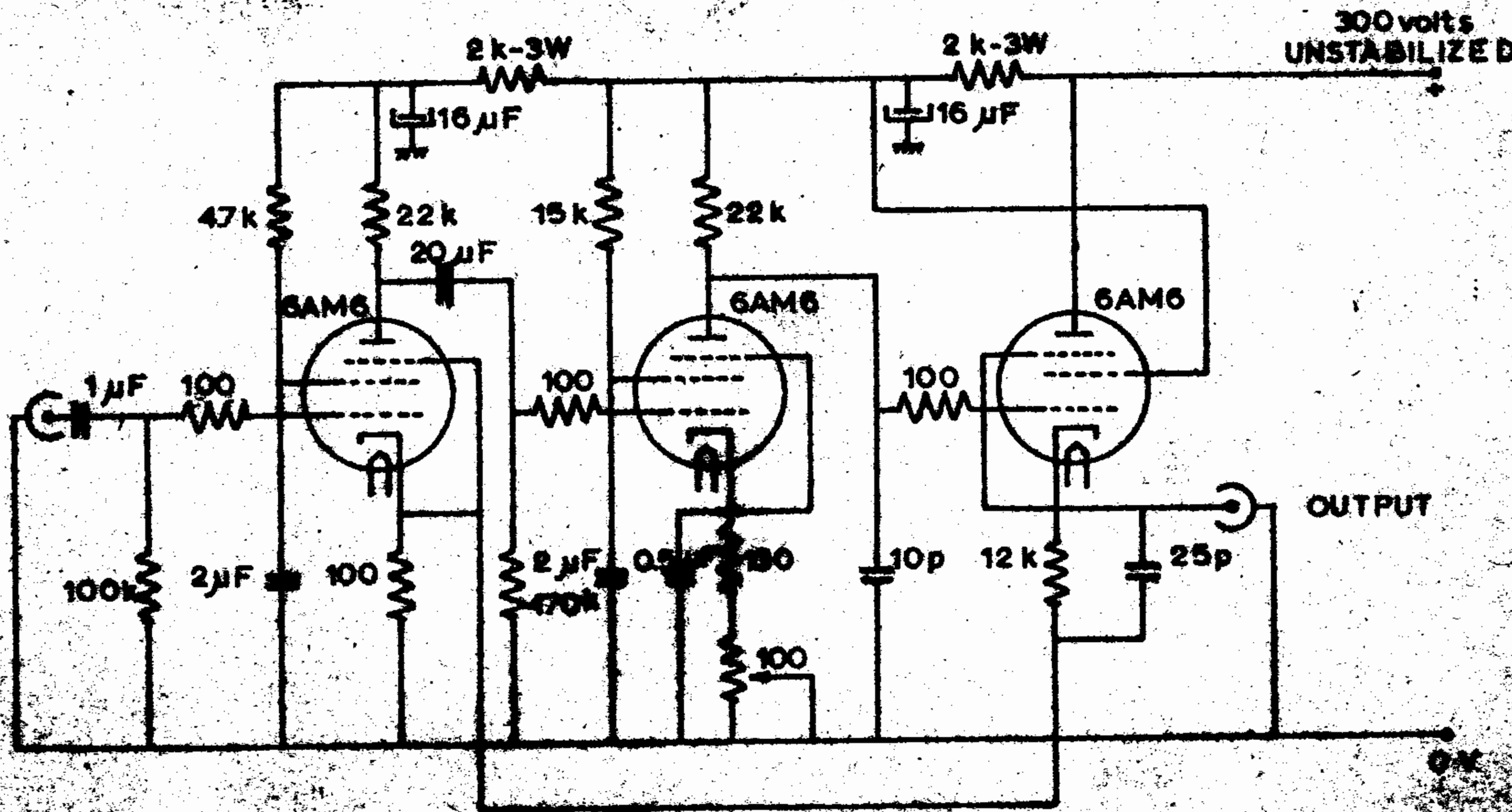

FIG. 11. MAIN AMPLIFIER

SECTION (5)

EXPERIMENTAL RESULTS

Recording of neutron counting rates have been done for the interval December 1960 - April 1961. During that time some interruptions occurred due to instrument or recording failures. As a matter of fact no data at all is available for the month of February 1961 due to a failure of the movie camera. This was only detected after the film roll of that month was developed.

The results of the recording are tabulated in the subsequent pages. To each month corresponds three tables. Table 1 gives the total bihourly counts of sections A and B (scale factor = 10). Table b gives the bihourly values of pressure in units of 0.1 mm Hg. to these values 7 000 has to be added. Table c gives the bihourly counting rate as in Table a but corrected for barometric pressure at 760 mm Hg. by means of the formula

$$N_{corrected} = N_{observed} \ \exp. (0.0096)(760 - p)$$

where p is the pressure in mm Hg. The above formula is a simple exponential absorption formula. The value 0.0096 is empirical and the number 760 is the average pressure at the location of the experiment. The above two numbers need not be very accurate for our purpose here! Following table c of each month is a graph representing the information in that table.

Solar flare data - as obtained from the bulletins* - is represented by symbols on the graph corresponding to table c. The position of the symbols on the graph marks the date and occurrence of the flare the shape

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*See Preface.

of the symbol corresponds to the importance of the flare according to the following notation:

■ = flares of importance 3

▲ = flares of importance 2

● = flares of importance 1.

Table 1.

December 1960

Uncorrected Intensity - Bihourly Values

(scale factor = 10)

UMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4	969	959	949	950	967	955	976	960	958	946	970	957
5	958	931	955	942	972	959	957	986	967	973	944	984
6	955	960	963	959	956	974	960	944	951	948	954	963
7					957	956	962	970	938	961	943	957
8	931	956	958	955	952	966	958	959	927	941	943	925
9	914	920	932	946	924						944	938
10	943	937	1007	1022	1038	1032	1061	1026	997	1008	1022	1004
11	995	1000	989	982	949	928	952	954	951	935	929	956
12	957	953	941	924	927	948	928	963	947	941	949	974
13	947	976	939	990	990	948	963	923	960	949	942	953
14	960	926	932	949	924	950	936	928	901	918	891	919
15	906	914	938	924	944	924	973	976	987	987	998	992
16	966	984	971	958	988	1002	990	970	961	970	1003	981
17	982	984	968	914	926	925					926	
18					952	951	961	937	950	933	935	952
19	930	934	947	914	940	952	934	952	921	951	914	948
20	952	962	951	940	956	974	941	966	931	947	924	945
21	922	904	926									
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Table 1[illegible]

December 1960

Barometric Readings - Unit 0.1 mm Hg

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4	610	610	610	610	604	600	598	600	604	610	612	612
5	611	611	615	620	615	610	610	610	610	610	609	605
6	602	600	605	611	611	610	610	612	620	622	622	621
7					645	629	628	631	631	635	635	634
8	630	631	640	640	632	625	630	630	630	641	635	630
9	640	640	644	650	647						648	640
10	638	635	637	642	638	630	629	627	630	629	621	620
11	620	618	621	624	620	611	612	612	619	617	616	611
12	605	602	608	629	626	616	601	599	599	604	602	606
13	605	595	596	594	595	591	602	625	598	598	598	612
14	619	618	626	630	630	623	625	629	634	639	629	637
15	634	634	640	645	642	636	632	631	636	659	640	639
16	640	637	639	643	640	635	632	630	635	634	633	629
17	626	625	629	631	629	620					620	
18					631	624	616	621	620	617	613	618
19	614	610	618	624	620	611	611	610	616	619	613	617
20	615	611	608	616	616	606	612	612	616	616	615	619
21	617	620	627									
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Average Pressure of Month = 762.1 mm Hg.

Table 1 c

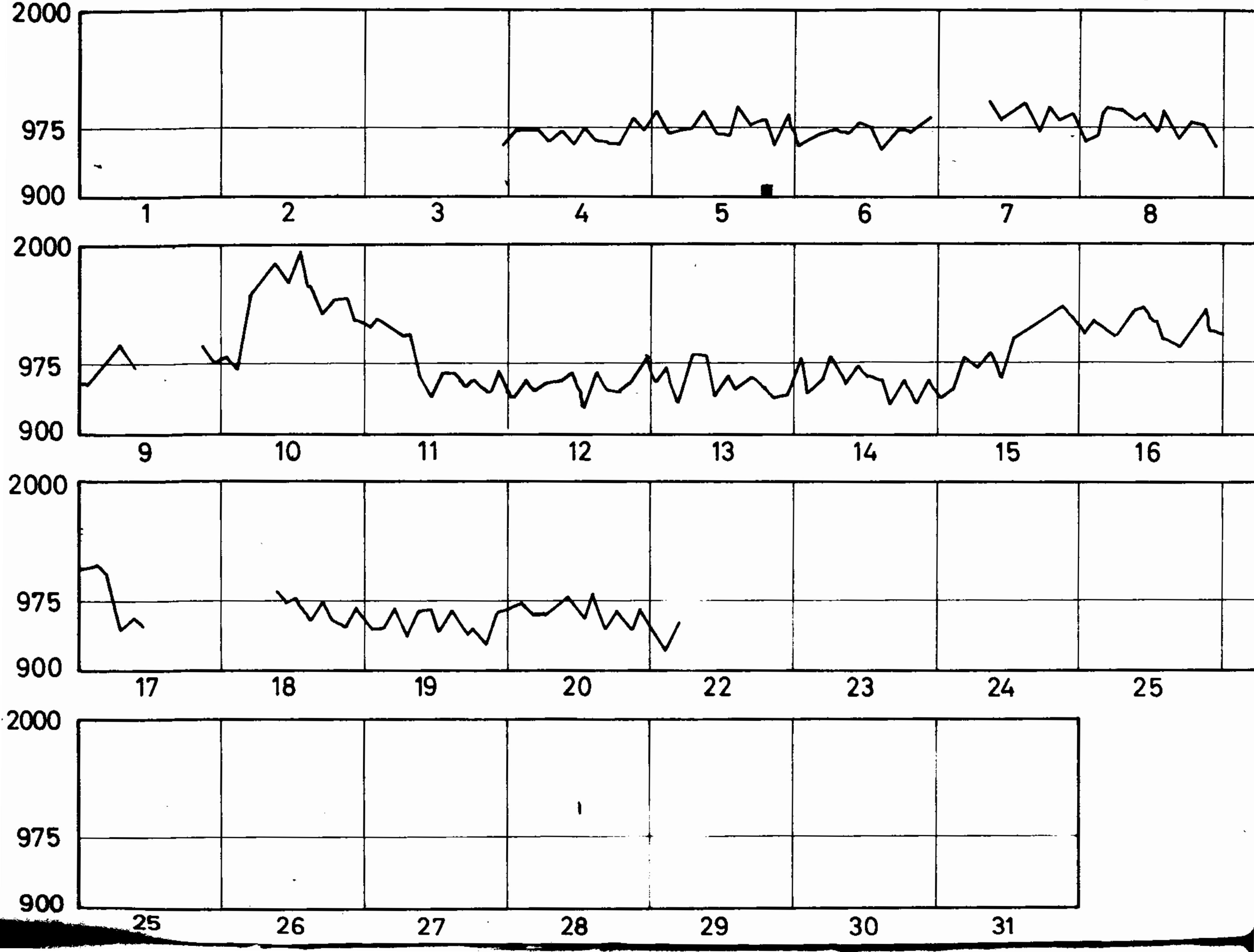
December 1960

Corrected Intensity - Bihourly Values

(scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4	970	969	969	960	971	955	974	960	958	956	983	970
5	969	942	970	962	990	969	967	976	977	983	953	98[illegible]
6	957	960	968	971	967	984	[illegible]	952	974	970	976	984
7					1002	985	[illegible]	1005	969	996	982	991
8	961	967	998	995	984	991	968	989	963	982	978	955
9	954	969	976	996	971						[illegible]	978
10	981	972	1044	1064	1076	1062	[illegible]	1053	1027	1037	1043	1024
11	1015	1018	1011	1006	963	959	964	962	950	952	945	967
12	942	955	945	953	953	964	929	964	946	945	951	980
13	952	971	934	984	985	937	961	948	958	947	940	941
14	973	944	958	979	954	973	961	957	935	957	930	956
15	940	948	978	964	986	960	1005	1007	1023	1026	1038	1031
16	1006	1021	1010	1001	1028	1035	1022	1000	994	1004	1036	[illegible]
17	1008	1004	997	945	955	945					946	
18					983	975	977	958	970	959	948	970
19	944	944	965	938	960	963	945	962	937	970	927	965
20	967	975	959	956	972	980	953	978	947	963	932	964
21	932	924	953									
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Monthly Average = 975



2000
975
900
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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30
31

BI-HOURLY INTENSITIES OF NEUTRONS DEC. 1960

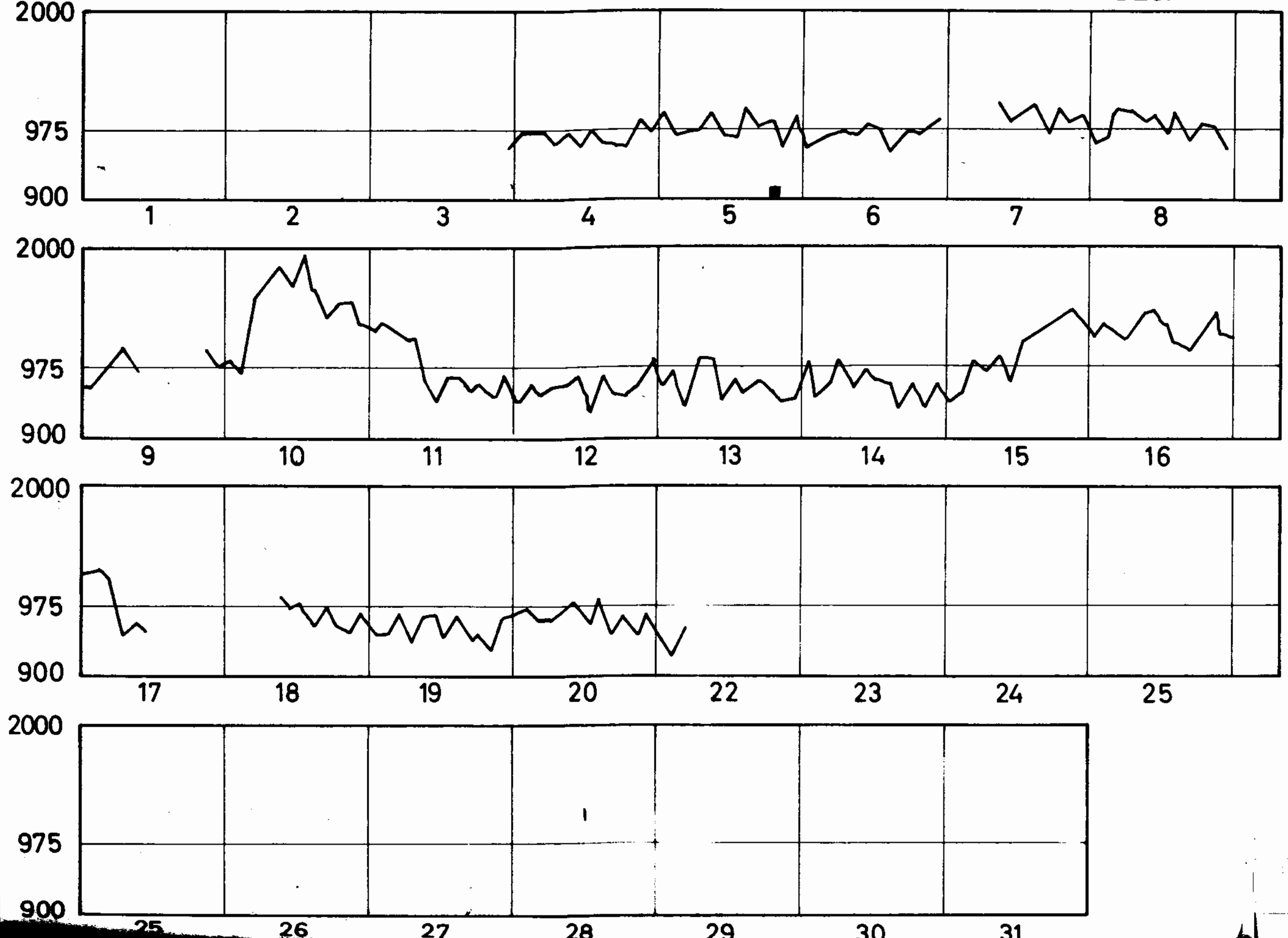


TABLE 2

January 1961

Uncorrected Intensity - Bihourly Values

(scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8											1213	1212
9	1204	1189	1167	1194	1200	1220	1208	1208	1233	1238	1209	1191
10	1230	1214	1217	1174	1175	1238		1203	1180	1190	1192	1201
11	1185	1161	1179	1158	1179	1185	1172	1149	1172	1159	1123	1167
12	1129	1142	1131	1127	1141	1148	1133	1139	1135	1137	1123	1128
13	1155	1145	1146	1158	1147	1151	1179	1155	1144	1161	1157	1163
14	1136	1151	1127	1167	1171	1165	1172	1173	1168	1179	1177	1188
15	1208	1152	1155	1173	1169	1182	1175	1167	1168	1169	1161	1154
16	1158	1143	1144	1133	1144	1181	1192	1179	1166	1200	1185	1191
17	1212	1203	1216	1207	1229	1217	1252	1204	1254	1202	1202	1193
18	1202	1206	1207	1191	1210	1208	1214	1232	1211	1192	1190	1226
19	1192	1182	1199	1215	1232	1261	1237	1255	1239	1248	1248	1232
20	1239	1247	1216	1232	1232	1233	1243	1184	1203	1206	1216	1214
21	1195	1195	1191	1200	1165	1176	1172	1165	1085			1139
22	1125	1102	1120	1098	1100	1128	1131	1111	1102	1111		
23	1127	1122	1144	1126	1129	1140	1110	1099	1105	1132	1135	1121
24	1157	1125	1112	1133	1151	1124	1141	1169	1139	1174	1156	1182
25	1183	1202	1214	1195	1241	1254	1258	1256	1263	1226	1257	1215
26	1257	1246	1202	1210	1193	1185	1197	1167	1180	1179	1155	1185
27	1154	1160	1155	1151	1171	1161	1186	1165	1139	1123	1165	1156
28	1152	1154	1160	1159	1168	1161	1180	1165	1159	1155	1167	1170
29	1144	1155	1204	1192	1153	1208	1182	1156	1189	1166	1219	1170
30	1198	1191	1216	1188	1189	1197	1169	1187	1184	1144	1196	1198
31	1199	1216	1198	1188	1156	1200		1218	1235	1202	1245	1214

Table 2 b

January 1961

Barometric Readings - Unit = 0.1 mm Hg

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8											610	605
9	602	600	600	600	590	575	571	576	575	575	582	590
10	591	588	589	595	594	587	589	590	593	597	600	600
11	603	606	610	618	618	611	613	615	628	631	639	640
12	641	648	654	660	660	653	650	652	659	660	660	656
13	655	651	658	660	657	651	647	642	648	647	644	640
14	638	634	640	641	638	627	627	621	620	617	611	607
15	600	611	619	625	628	622	622	631	640	640	642	642
16	641	642	643	648	646	630	630	619	620	615	610	603
17	597	580	575	581	580	569	570	580	588	590	596	591
18	581	588	591	588	594	588	588	590	592	594	599	595
19	590	588	581	580	572	551	552	548	541	547	550	551
20	551	555	559	560	560	559	560	566	572	576	579	583
21	290	291	600	613	620	621	626	636	646			658
22	659	659	663	669	668	662	665	669	670	670		
23	660	656	656	660	660	653	650	652	658	658	659	655
24	651	650	655	660	665	644	639	632	630	624	621	611
25	600	595	588	584	570	560	547	536	536	536	542	553
26	560	560	573	587	590	590	590	593	610	616	619	620
27	620	621	626	634	633	630	630	630	632	634	634	630
28	630	628	630	636	633	623	620	620	621	620	621	620
29	619	613	613	618	614	600	598	600	599	600	595	600
30	599	590	601	608	604	604	610	610	610	612	611	611
31	610	606	606	605	598	588	581	580	580	575	570	565

Average Pressure of Month = 761.2 mm Hg.

Table 2 c

January 1961

Corrected Intensities - Bihourly Values

(scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8											1223	1207
9	1206	1189	1167	1194	1190	1195	1180	1174	1208	1213	1191	1181
10	1221	1202	1206	1170	1170	1225		1193	1173	1189	1192	1201
11	1188	1167	1189	1176	1197	1196	1185	1164	1200	1190	1162	1207
12	1170	1140	1185	1187	1201	1201	1183	1191	1194	1197	1183	1184
13	1210	1196	1204	1218	1204	1202	1216	1197	1192	1208	1201	1203
14	1174	1185	1167	1208	1209	1192	1199	1194	1188	1196	1188	1195
15	1208	1163	1174	1198	1197	1204	1202	1198	1208	1209	1203	1176
16	1179	1185	1187	1181	1190	1211	1222	1198	1186	1215	1193	1194
17	1209	1183	1191	1188	1207	1186	1222	1184	1222	1192	1198	1184
18	1191	1194	1198	1189	1204	1196	1202	1222	1203	1186	1189	1221
19	1182	1170	1180	1195	1204	1212	1189	1203	1180	1195	1198	1183
20	1190	1204	1175	1192	1192	1192	1203	1150	1175	1182	1195	1197
21	1185	1186	1191	1213	1185	1197	1198	1201	1131			1197
22	1184	1161	1183	1167	1168	1190	1196	1180	1179	1181		
23	1187	1178	1200	1186	1189	1193	1160	1151	1163	1190	1194	1180
24	1188	1175	1167	1193	1216	1168	1180	1201	1169	1183	1177	1193
25	1183	1197	1202	1179	1211	1214	1205	1192	1200	1162	1199	1168
26	1197	1206	1175	1197	1183	1175	1187	1160	1190	1195	1174	1205
27	1174	1181	1175	1185	1204	1191	1216	1195	1171	1157	1199	1186
28	1182	1182	1190	1195	1201	1184	1200	1185	1180	1175	1188	1190
29	1163	1168	1217	1210	1167	1208	1180	1156	1188	1160	1214	1170
30	1197	1181	1217	1196	1198	1201	1179	1197	1194	1156	1207	1209
31	1209	1222	1204	1193	1154	1188		1198	1215	1177	1215	1179

Monthly average = 1190.

Table 2 c

January 1961

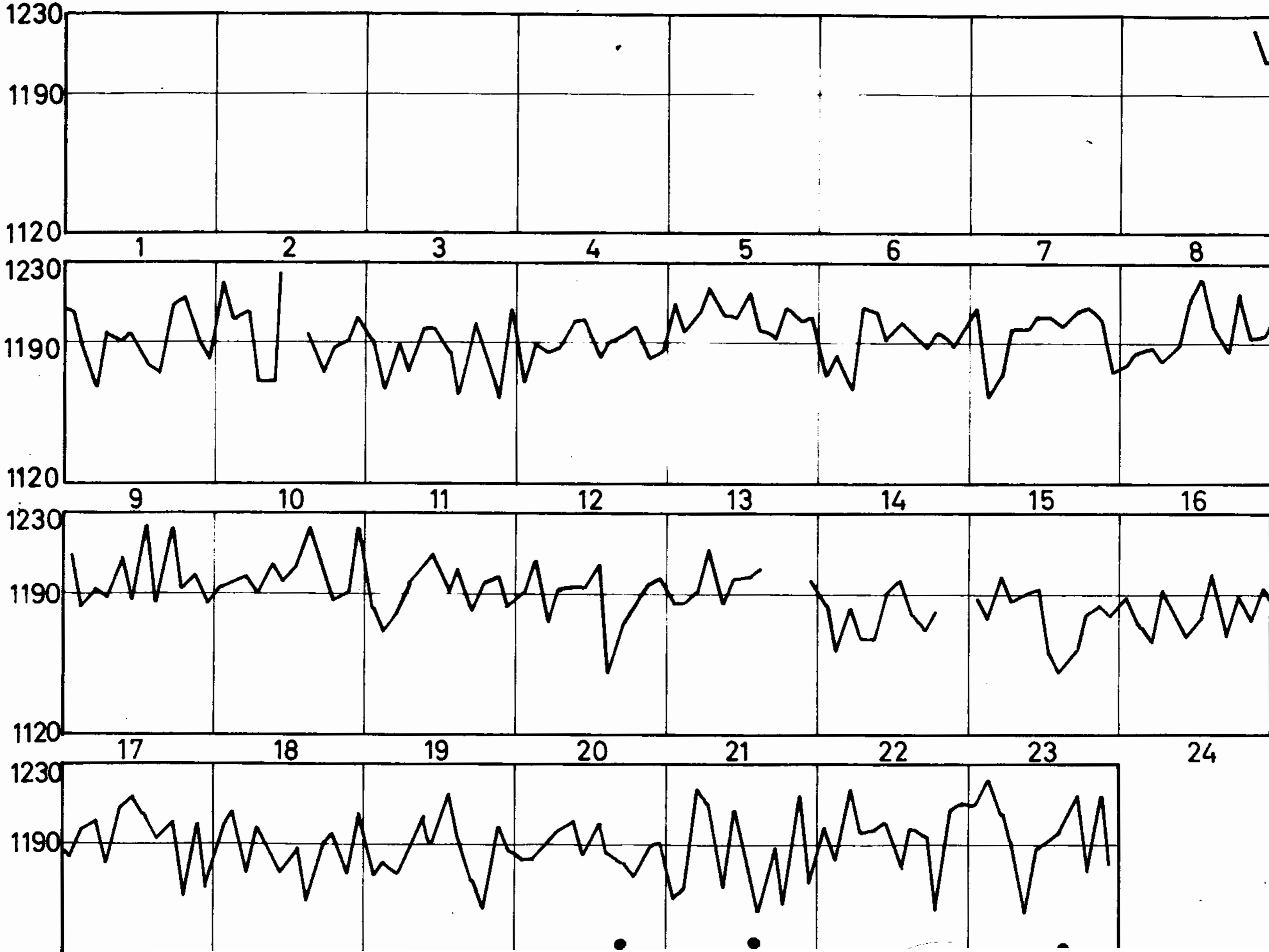
Corrected Intensities - Bihourly Values

(scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8											1223	1207
9	1206	1189	1167	1194	1190	1195	1180	1174	1208	1213	1191	1181
10	1221	1202	1206	1170	1170	1225		1193	1173	1189	1192	1201
11	1188	1167	1189	1176	1197	1196	1185	1164	1200	1190	1162	1207
12	1170	1140	1185	1187	1201	1201	1183	1191	1194	1197	1183	1184
13	1210	1196	1204	1218	1204	1202	1216	1197	1192	1208	1201	1203
14	1174	1185	1167	1208	1209	1192	1199	1194	1188	1196	1188	1195
15	1208	1163	1174	1198	1197	1204	1202	1198	1208	1209	1203	1176
16	1179	1185	1187	1181	1190	1211	1222	1198	1186	1215	1193	1194
17	1209	1183	1191	1188	1207	1186	1222	1184	1222	1192	1198	1184
18	1191	1194	1198	1189	1204	1196	1202	1222	1203	1186	1189	1221
19	1182	1170	1180	1195	1204	1212	1189	1203	1180	1195	1198	1183
20	1190	1204	1175	1192	1192	1192	1203	1150	1175	1182	1195	1197
21	1185	1186	1191	1213	1185	1197	1198	1201	1131			1197
22	1184	1161	1183	1167	1168	1190	1196	1180	1179	1181		
23	1187	1178	1200	1186	1189	1193	1160	1151	1165	1190	1194	1180
24	1188	1175	1167	1193	1216	1168	1180	1201	1169	1183	1177	1193
25	1183	1197	1202	1179	1211	1214	1205	1192	1200	1162	1199	1168
26	1197	1206	1175	1197	1183	1175	1187	1160	1190	1195	1174	1205
27	1174	1181	1175	1185	1204	1191	1216	1195	1171	1157	1199	1186
28	1182	1182	1190	1195	1201	1184	1200	1185	1180	1175	1188	1190
29	1163	1168	1217	1210	1167	1208	1180	1156	1188	1160	1214	1170
30	1197	1181	1217	1196	1198	1201	1179	1197	1194	1156	1207	1209
31	1209	1222	1204	1193	1154	1188		1198	1215	1177	1215	1179

Monthly average = 1190.

BI-HOURLY INTENSITIES OF NEUTRONS JAN. 1961



BI-HOURLY INTENSITIES OF NEUTRONS

JAN. 1961

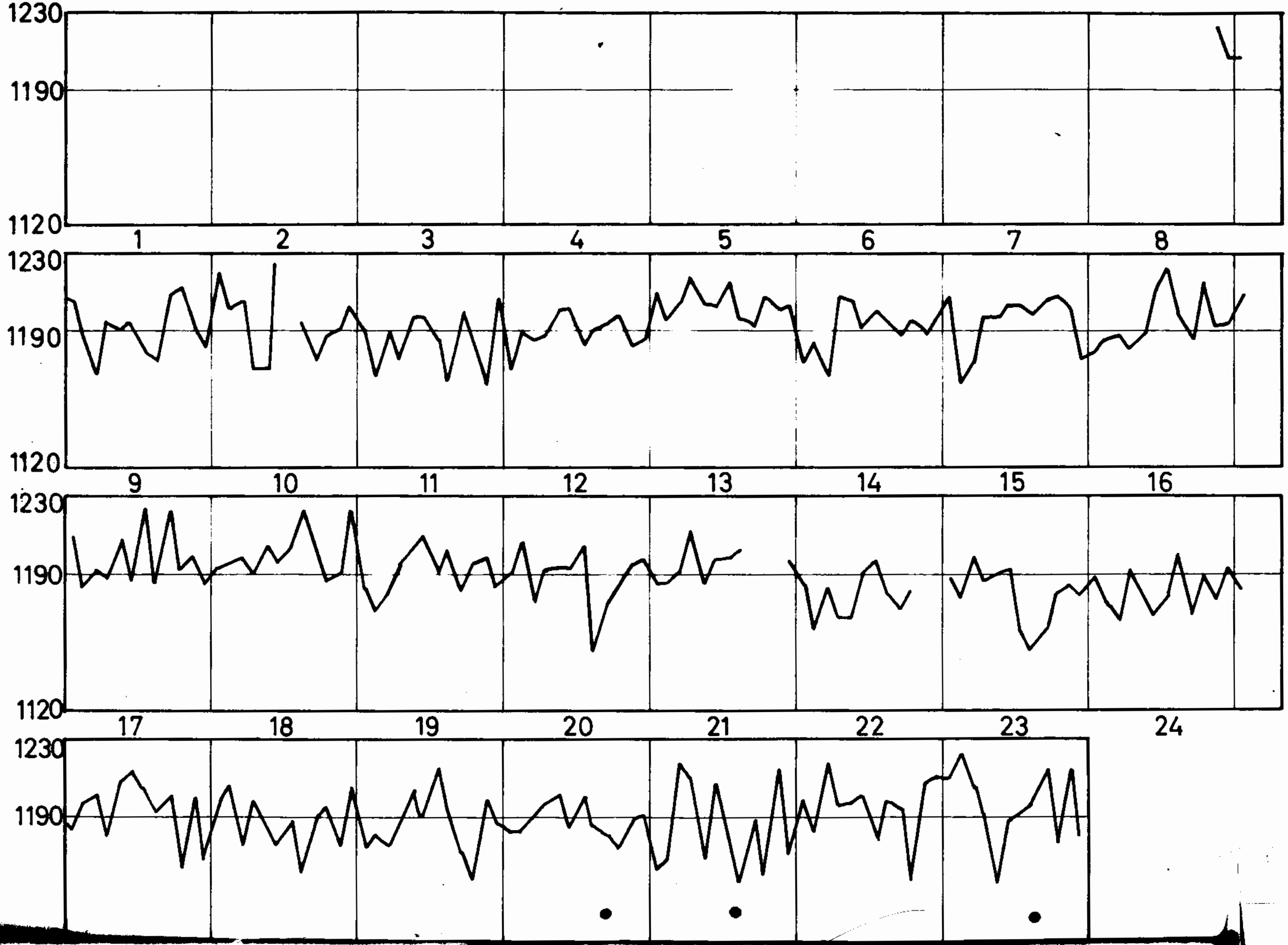


Table 3 a

March 1961

Uncorrected Intensity - Bihourly Value

(Scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15						1487	1474	1487	1452	1441	1414	1439
16	1423	1426	1423	1398	1413	1406	1415	1409	1395	1359	1335	1384
17	1362	1384	1358	1381	1389	1361	1385	1377	1394	1370	1366	1385
18	1384	1392	1400					1430	1420	1441	1450	1440
19	1425	1402	1435	1418	1414	1430	1422	1432	1415	1399	1410	1396
20	1395	1403	1412	1363	1377	1417	1406	1399	1367	1362	1385	1375
21	1357	1348	1364	1332	1350	1351	1385	1353	1350	1345	1346	1353
22	1328	1348	1356	1334	1352	1365	1361	1347	1370	1400	1371	1379
23	1356	1398	1372	1385	1364	1411	1381	1402	1403	1407	1431	1403
24	1405	1427	1410	1432	1456	1470	1481	1486	1441	1429	1477	1472
25	1476	1484	1460	1469	1443	1362	1445	1452	1445	1412	1422	1428
26	1414	1419	1385	1386	1403	1403	1389	1404	1394	1375	1382	1389
27	1398	1390	1398	1404	1418	1434	1447					
28					1548	1554	1550	1521	1531	1514	1508	1513
29	1502	1509	1488	1512	1488	1479	1481	1463	1466	1460	1488	1466
30	1493	1490	1437	1478	1487	1474	1485	1479	1446	1445	1416	1434
31	1445	1443	1439	1417	1422	1415	1418	1441	1401	1372	1382	1381

Table 3 b

March 1961

Barometric Readings - Unit 0.1 mm Hg

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15						560	554	561	572	584	587	590
16	590	591	597	606	612	612	610	611	619	622	625	627
17	626	628	633	646	641	635	626	623	624	626	623	617
18	611	610	612					582	581	580	579	573
19	571	570	578	588	591	588	585	592	594	600	600	598
20	298	597	602	611	614	614	617	620	624	630	630	630
21	630	630	639	649	650	648	641	641	649	653	650	650
22	648	648	652	660	660	650	644	643	641	640	638	631
23	628	623	630	630	626	617	612	612	611	606	600	597
24	588	583	580	577	574	560	552	558	561	563	566	564
25	558	558	561	570	576	578	579	580	582	589	591	594
26	598	601	608	618	620	620	617	616	620	626	626	619
27	610	608	610	606	600	590	579					
28					501	501	508	515	520	521	523	524
29	523	528	536	541	549	550	551	558	560	563	561	555
30	550	548	546	553	556	557	557	559	564	568	571	573
31	570	573	584	590	595	594	592	594	603	606	605	603

Average Pressure of Month = 759.5 mm Hg.

Table 3 b

March 1961

Barometric Readings - Unit 0.1 mm Hg

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15						560	554	561	572	584	587	590
16	590	591	597	606	612	612	610	611	619	622	625	627
17	626	628	633	646	641	635	626	623	624	626	623	617
18	611	610	612					582	581	580	579	573
19	571	570	578	588	591	588	585	592	594	600	600	598
20	298	597	602	611	614	614	617	620	624	630	630	630
21	630	630	639	649	650	648	641	641	649	653	650	650
22	648	648	652	660	660	650	644	643	641	640	638	631
23	628	623	630	630	626	617	612	612	611	606	600	597
24	588	583	580	577	574	560	552	558	561	563	566	564
25	558	558	561	570	576	578	579	580	582	589	591	594
26	598	601	608	618	620	620	617	616	620	626	626	619
27	610	608	610	606	600	590	579					
28					501	501	508	515	520	521	523	524
29	523	528	536	541	549	550	551	558	560	563	561	555
30	550	548	546	553	556	557	557	559	564	568	571	573
31	570	573	584	590	595	594	592	594	603	606	605	603

Average Pressure of Month = 759.5 mm Hg.

Table 3 c

March 1961

Corrected Intensity - Bihourly Value

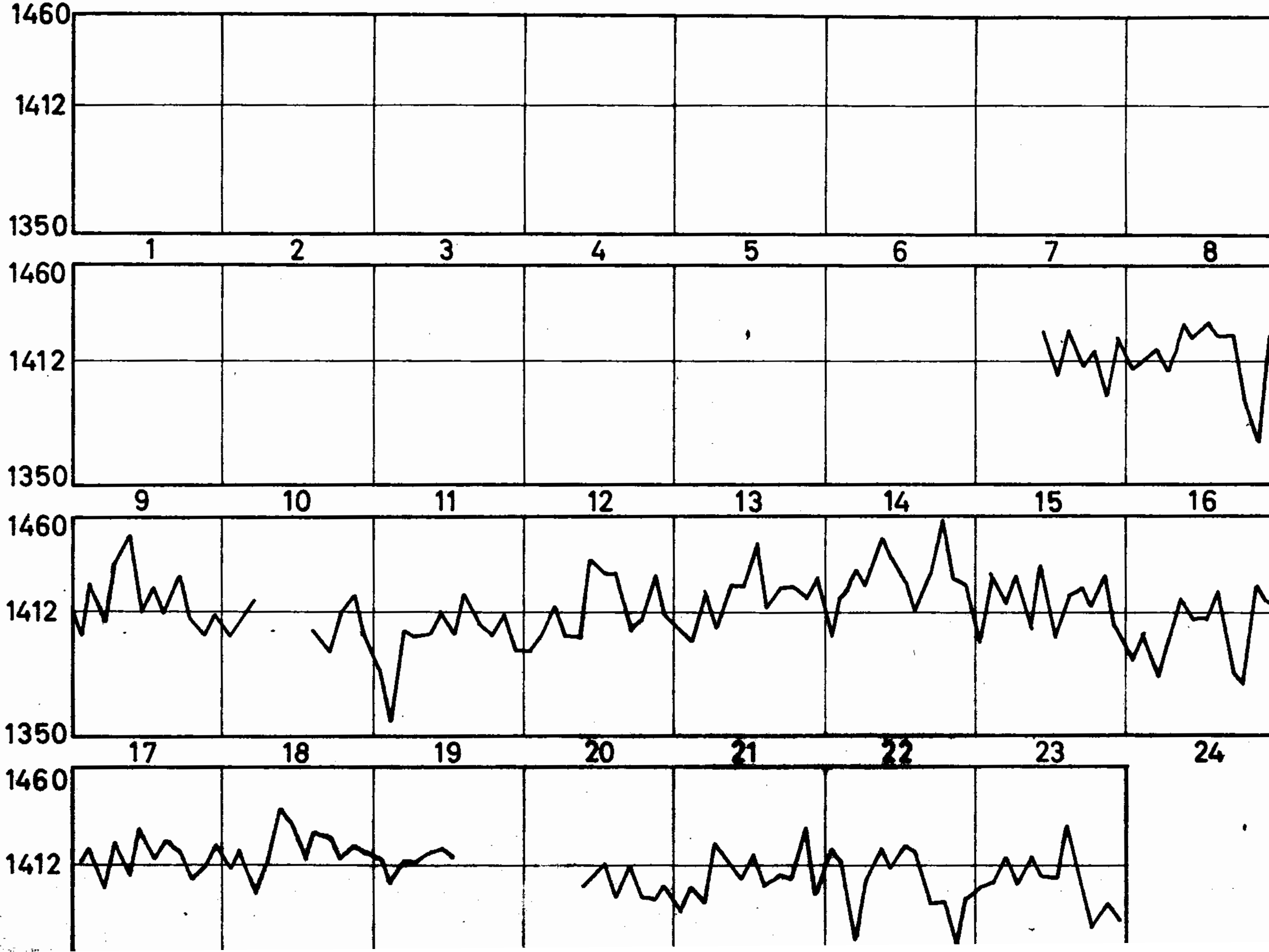
(scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15						1427	1405	1428	1410	1417	1395	1424
16	1408	1412	1418	1407	1431	1424	1430	1425	1424	1392	1372	1425
17	1401	1426	1408	1441	1450	1413	1424	1412	1430	1409	1401	1410
18	1400	1407	1418					1403	1392	1411	1419	1400
19	1382	1357	1402	1400	1406	1412	1400	1420	1406	1399	1410	1393
20	1392	1400	1415	1399	1398	1438	1431	1429	1403	1407	1430	1410
21	1402	1397	1423	1406	1425	1423	1446	1414	1424	1424	1421	1428
22	1400	1420	1434	1424	1449	1440	1427	1411	1431	1460	1428	1425
23	1398	1432	1417	1430	1403	1436	1399	1420	1425	1416	1431	1404
24	1387	1402	1380	1397	1417	1410	1409	1423	1382	1375	1426	1418
25	1413	1421	1401	1424	1407	1429	1414	1422	1418	1406	1409	1419
26	1411	1421	1397	1413	1439	1433	1414	1428	1424	1414	1421	1418
27	1413	1402	1413	1413	1418	1419	1416					
28					1399	1405	1412	1394	1411	1395	1393	1399
29	1387	1401	1392	1423	1412	1404	1417	1400	1406	1405	1429	1398
30	1418	1412	1376	1404	1421	1410	1421	1418	1392	1397	1372	1394
31	1400	1403	1415	1402	1415	1406	1406	1432	1406	1381	1390	1386

Monthly Average = 1412

BI-HOURLY INTENSITIES OF NEUTRONS

MAR. 196



BI-HOURLY INTENSITIES OF NEUTRONS MAR. 196

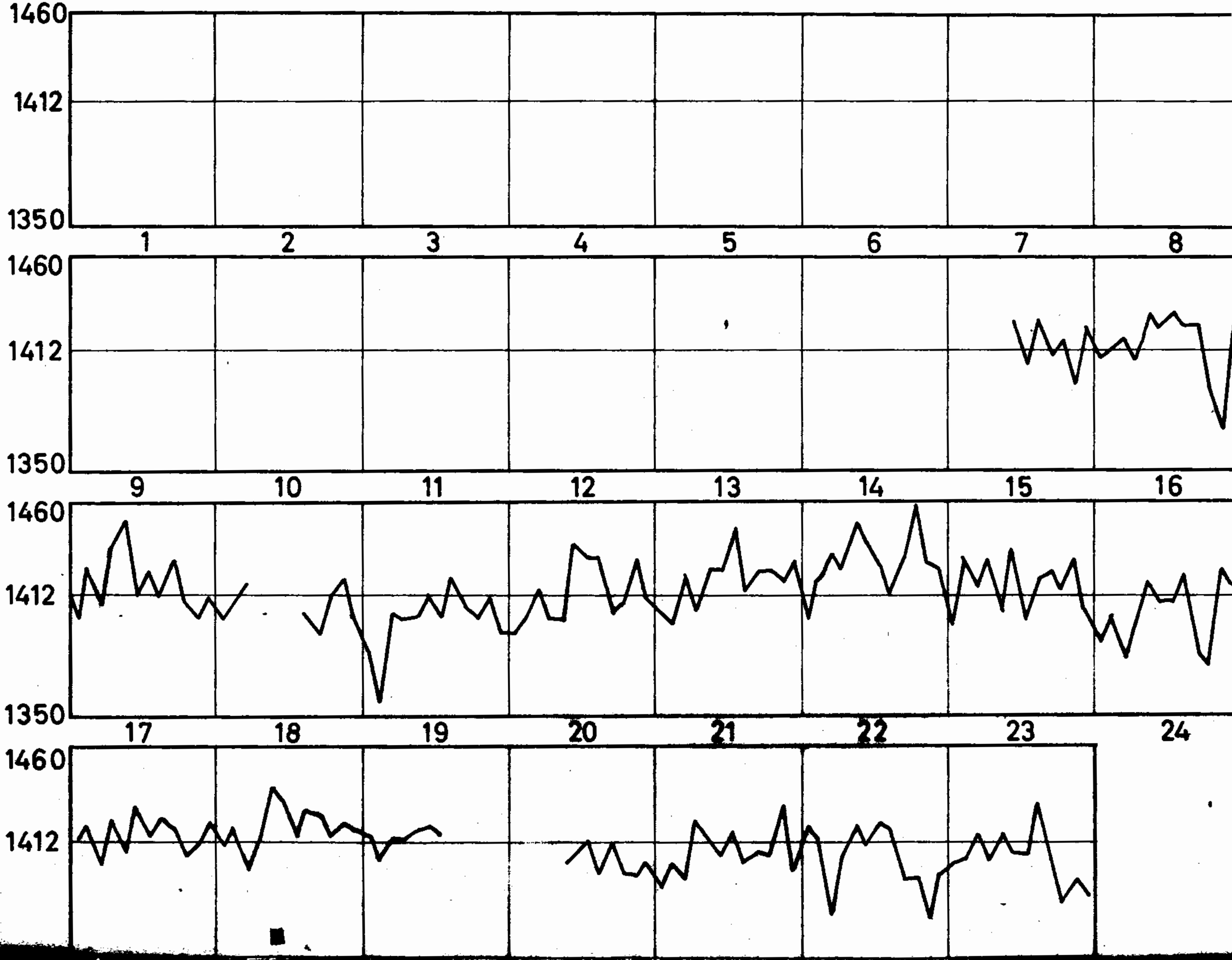


Table 4 a

April 1961

Uncorrected Intensity - Bihourly Values

(Scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1	1404	1394	1383	1370	1396	1358	1357	1395	1385	1375	1360	1377
2	1377	1351	1371	1365	1355	1403	1410	1389	1400	1425	1419	1434
3	1430	1411	1453	1431	1442	1460	1477	1455	1469	1471	1456	1459
4	1475	1499	1469	1451	1464	1511	1516	1527	1504	1497	1517	1516
5	1504	1483	1513	1481	1498	1486	1476	1474	1468	1464	1447	1441
6	1481	1496	1444	1484	1462	1469	1481	1475	1455	1448	1454	1436
7	1453	1429	1468	1468	1448	1436	1435	1476	1465	1453	1459	1453
8	1450	1462	1453	1487	1481	1465	1472	1470	1456	1462	1455	1470
9	1456	1460	1444	1430	1456	1463	1456	1436	1416	1431	1402	1387
10	1406	1439	1439	1401	1416	1425	1393	1406	1417	1434	1433	1417
11	1425	1453			1471	1485	1508	1523	1507	1471	1454	1474
12	1484	1471	1479	1494	1477	1494	1468	1477	1502	1470	1468	1450
13	1489	1468	1460	1488	1476	1465	1488	1463	1487	1479	1461	1447
14	1464	1464	1462	1445	1411	1437	1404	1414	1436	1389	1427	1421
15	1433	1437	1454	1431	1408	1430	1410	1410	1401	1389	1376	1383
16	1385	1405	1377	1460	1355	1399	1243	1318	1388	1351	1350	1393
17	1374	1334	1369	1353	1345	1347	1346	1371	1332	1356	1362	1362
18	1375	1398	1376	1372	1338	1366	1390	1362	1371	1372	1368	1381
19	1376	1362	1387	1375	1373	1388	1359	1402	1374	1404	1400	1399
20	1416	1426	1428	1403	1433	1397	1424	1451	1448	1452	1435	1463
21	1456	1439	1460	1461	1459	1485	1481	1484	1485	1462	1465	1460
22	1485	1475	1465	1464	1466	1482	1461	1483	1470	1451	1453	1463
23	1458	1454	1473	1459	1425	1470	1456	1448	1463	1462	1454	1463
24	1444	1437	1459	1451	1415	1454	1446	1433	1451	1439	1442	1452
25	1475	1460	1450	1450	1436	1444	1432	1451	1452	1453	1466	1462
26	1472	1495	1488	1447	1465	1494	1489	1445	1443	1449	1435	1404
27	1415	1408	1432	1408	1421	1459	1440	1423	1419	1445	1459	1440
28	1446	1454	1484	1464	1463	1475	1504	1467	1527	1517	1490	1452
29	1470	1468	1480	1432	1464	1490	1446	1456	1442	1448	1398	1417
30	1406	1395	1405	1399	1404	1406	1390	1409	1390	1394	1402	1411
31												

Table 4 b

April 1961

Barometric Readings - Unit 0.1 mm Hg.

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1	604	610	620	628	630	630	630	630	637	641	641	639
2	631	630	632	638	633	628	616	615	609	600	595	592
3	580	580	580	581	582	581	580	577	578	575	571	566
4	560		560	560	555	547	536	528	529	530	530	532
5	530	534	541	549	550	550	550	553	559	568	570	569
6	565	567	571	576	576	573	571	570	572	576	579	575
7	570	572	579	583	585	582	580	580	582	585	585	579
8	572	508	570	570	570	568	566	570	575	575	571	570
9	570	572	579	587	590	590	589	590	594	602	602	604
10	596	596	607	615	619	615	609	607	601	604	600	585
11	580	574			568	558	541	532	538	540	549	550
12	550	550	556	561	565	561	560	561	566	570	569	560
13	551	551	556	560	563	563	560	560	562	570	570	569
14	563	565	571	576	580	577	570	570	572	579	580	580
15	580	581	589	594	600	600	597	598	600	603	605	602
16	600	604	609	613	620	619	613	613	617	620	620	620
17	620	625	631	637	640	637	631	630	630	635	636	631
18	630	630	634	638	640	637	630	629	632	635	636	633
19	626	620	622	625	625	620	617	614	616	614	608	603
20	599	597	598	599	599	594	589	583	580	580	576	573
21	570	566	570	570	568	560	559	559	561	567	562	560
22	559	559	566	570	573	571	570	569	568	574	578	573
23	571	576	580	583	581	576	574	574	571	573	578	572
24	571	573	581	587	587	583	579	580	577	583	581	576
25	572	570	573	578	579	580	576	570	572	574	568	559
26	548	546	558	560	557	562	571	572	578	584	586	588
27	588	589	596	600	597	593	586	581	582	581	583	575
28	570	568	565	567	569	560	552	542	530	531	538	544
29	549	552	563	572	578	580	583	583	590	600	604	602
30	603	606	612	619	622	620	618	613	615	615	610	608
31												

Average Pressure of Month =

Table 4 b

April 1961

Barometric Readings - Unit 0.1 mm Hg.

(Constant subtracted = 7000)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1	604	610	620	628	630	630	630	630	637	641	641	639
2	631	630	632	638	633	628	616	615	609	600	595	592
3	580	580	580	581	582	581	580	577	578	575	571	566
4	560		560	560	555	547	536	528	529	530	530	532
5	530	534	541	549	550	550	550	553	559	568	570	569
6	565	567	571	576	576	573	571	570	572	576	579	575
7	570	572	579	583	585	582	580	580	582	585	585	579
8	572	508	570	570	570	568	566	570	575	575	571	570
9	570	572	579	587	590	590	589	590	594	602	602	604
10	596	596	607	615	619	615	609	607	601	604	600	585
11	580	574			568	558	541	532	538	540	549	550
12	550	550	556	561	565	561	560	561	566	570	569	560
13	551	551	556	560	563	563	560	560	562	570	570	569
14	563	565	571	576	580	577	570	570	572	579	580	580
15	580	581	589	594	600	600	597	598	600	603	605	602
16	600	604	609	613	620	619	613	613	617	620	620	620
17	620	625	631	637	640	637	631	630	630	635	636	631
18	630	630	634	638	640	637	630	629	632	635	636	633
19	626	620	622	625	625	620	617	614	616	614	608	603
20	599	597	598	599	599	594	589	583	580	580	576	573
21	570	566	570	570	568	560	559	559	561	567	562	560
22	559	559	566	570	573	571	570	569	568	574	578	573
23	571	576	580	583	581	576	574	574	571	573	578	572
24	571	573	581	587	587	583	579	580	577	583	581	576
25	572	570	573	578	579	580	576	570	572	574	568	559
26	548	546	558	560	557	562	571	572	578	584	586	588
27	588	589	596	600	597	593	586	581	582	581	583	575
28	570	568	565	567	569	560	552	542	530	531	538	544
29	549	552	563	572	578	580	583	583	590	600	604	602
30	603	606	612	619	622	620	618	613	615	615	610	608
31												

Average Pressure of Month =

Table 4 c

April 1961

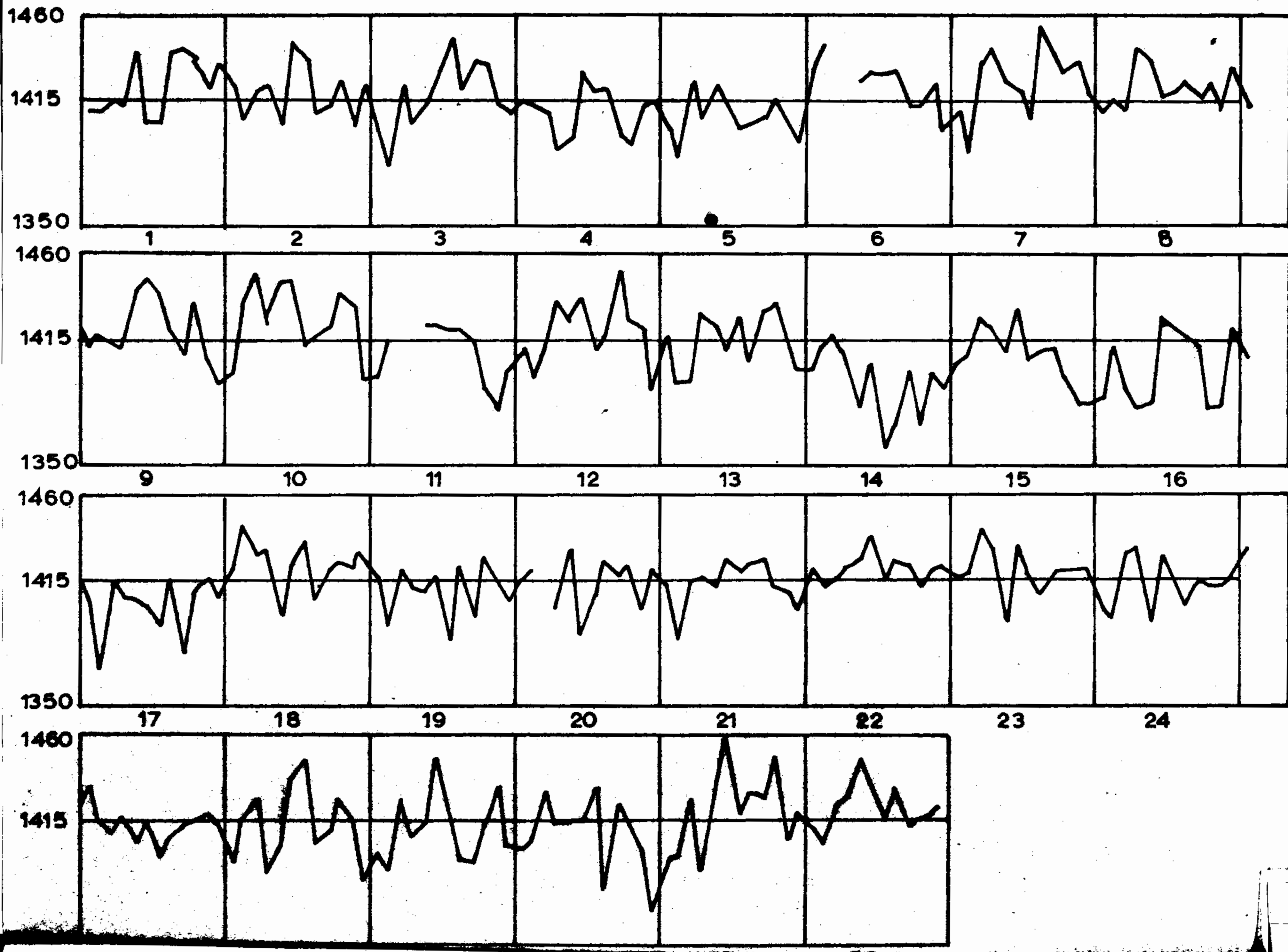
Corrected Intensity - Bihourly Values

(Scale factor = 10)

GMT Day	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
1	410	409	413	412	441	403	402	440	440	436	421	436
2	423	406	419	422	404	446	434	408	413	425	402	422
3	400	381	423	402	415	431	447	420	436	433	412	408
4	415		409	391	396	431	420	419	397	392	412	414
5	400	384	424	404	423	411	401	403	406	416	402	394
6	428	446			426	428	427	430	413	412	422	400
7	408	387	436	442	425	419	405	446	438	430	436	421
8	408	414	408	442	436	417	421	425	418	424	411	435
9	411	418	412	410	441	448	440	421	407	434	405	393
10	400	433	449	423	445	447	412	416	419	440	433	394
11	395	414			423	422	420	421	414	381	377	399
12	410	396	413	435	424	435	408	418	451	425	421	390
13	414	393	394	428	420	409	428	403	430	434	416	400
14	400	411	418	409	381	402	359	369	401	367	397	391
15	403	408	425	422	408	430	405	407	410	394	384	385
16	385	411	390	380	385	428			413	381	380	423
17	404	371	415	408	405	402	392	416	377	408	416	408
18	420	443	427	429	398	422	435	406	419	424	422	431
19	415	392	420	413	410	418	384	423	398	425	412	404
20	414	421		401	431	388	407	425	418	422	400	422
21	411	388	415	416	411	425	419	422	426	412	408	400
22	423	413	414	419	425	438	416	426	422	412	420	422
23	417	418	443	433	396	434	417	409	419	421	421	421
24	400	396	430	431	395	428	414	403	416	413	415	416
25	433	415	409	412	404	414	398	406	410	414	418	400
26	393	414	425	387	400	437	445	403	410	425	414	386
27	397	391	426	408	416	448	420	394	392	416	433	402
28	401	406	431	414	416	415	432	380	422	413	397	368
29	343	396	424	390	431	460	420	430	427	448	404	420
30	411	404	423	428	447	436	417	429	412	416	417	423
31												

Average for Month = 1415

BI-HOURLY INTENSITIES OF NEUTRONS APRIL 1961



SECTION (6)

ANALYSIS OF RESULTS

The following tables show the date, time and importance of solar flares and the corresponding neutron counting rate averaged for two hours around the maximum time of the solar flare.

Table 5. Neutron Intensities During Solar Flare Time.

Month 2nd Year	Date of Flare	Time of Flare	Imp. of Flare	Count rate/2 Hr During max. of Flare s. f. = 10	Average Count Rate/2 Hr for Month s. f. = 10	% Deviation of Count Rate/2 Hr From Avg. During Flare
Dec. 1960	5	1832	3	980 ± 10	975	+0.5 ± 1%
Dec. 1960	14	1322	2	965 ± 10	975	-1 ± 1%
Jan. 1961	28	0656	1	1180 ± 11	1190	-1 ± 1%
Jan. 1961	29	1304	1	1180 ± 11	1190	-1 ± 1%
Jan. 1961	31	1514	1	1195 ± 11	1190	+.5 ± 1%
March 1961	26	1027	3	1427 ± 12	1412	1 ± %
April 1961	5	837	1	1415 ± 12	1415	0 ± %

The last column in the table corresponds to the percentage deviation of the counting rate at the time of the flare, from the average rate during the corresponding month. The calculation of the error in any counting rate is done by taking the square root of its value. Due to the large number of counts taken during a month, the error in the average for a month is negligible. The average count rate is not approximately the same except in the last two months because the number of counting tubes was not the same. During December, the pile had four tubes, in January it had five tubes and in March and April it had six tubes. As can be clearly seen in the last column of the upper table no significant result in the duration of counting rate was detected during the solar flare events. As a matter of fact during the whole period of study, no deviation from the average greater than + (4 ± 1)% was detected. This is shown in the following table.

Table 6. Maximum and Minimum Neutron Intensity During Months of Observation.

Month	Avg./2 Hr	Max. rate Above Avg.	Min. rate Below Avg.	Max. Dev. Above Avg.	Min. Dev. Below Avg.
Dec.	975	1090 ± 10	935 ± 10	(2 ± 1)%	(4 ± 1)%
Jan.	1190	1155 ± 11	1222 ± 11	(3 ± 1)%	(3 ± 1)%
March	1412	1460 ± 12	1357 ± 12	(3 ± 1)%	(4 ± 1)%
April	1415	1460 ± 12	1360 ± 12	(3 ± 1)%	(4 ± 1)%

SECTION (7)

CONCLUSION

In certain cases such as during the period of study undertaken here, flares do occur, without a corresponding increase in cosmic radiation. However, in other cases it has been observed that flares have produced an increase in cosmic radiation, sometimes of the order of 600 per cent or more.

In concluding this thesis, I would like to give a brief description of a theory concerning solar flares and cosmic rays as developed by Frior (10). Part of Frior's theory is based on the following main characteristics of cosmic radiation that develop - if they develop at all - during solar flares:

(1) The intensity changes are occasionally very large. For example, on 19 November 1949, a 600 per cent in cosmic radiation was detected at a certain observation station, Manchester (England).

(2) At a given location, the increase depends upon the detectors used. For example, on the 19th of November 1949, a neutron detector (low energy particle detector) at Manchester, indicated an increase of 600% whereas a meson detector (high energy detector) at the same location indicated an increase of only 11 per cent. This of course shows that variations respond more to low energy particles.

(3) The intensity increase observed varies greatly with geographical latitude and hence, also with geomagnetical latitude. For example, although a 600 per cent increase in cosmic radiation was observed in Manchester, England (Geog. Lat. 53.30° N; 2.15° W) no increase was observed in Huancayo, Peru (Geog. Lat. 12.0° S; 77.3° W).

In his theory, Frior assumes that the sun has no magnetic field and that charged particles are ejected during solar flares from the sun and reach the earth after being affected in a complicated manner by the earth's magnetic field. The trajectories of the particles were found by means of models devised by Brunberg (11). His calculation at the time when the sun is in the geomagnetic latitude leads to the division of the earth into three impact zones as is shown in the diagram below.

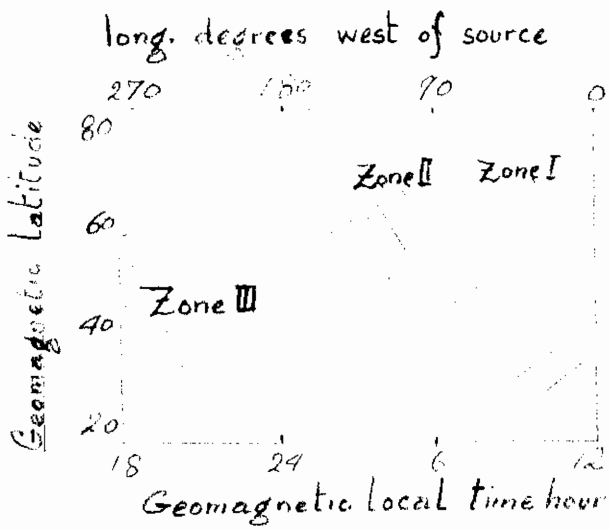


Figure 12. Frior's impact zones on the earth for particles arriving from the sun for particles with rigidities between 1 + 10 Gev. at the time when the sun lies in the geomagnetic equation (From Rossi (12)).

The first zone refers to particles arriving to the point of observation without crossing the equitorial plane. The second zone refers to particles reaching the point of observation after leaving once gone through the equitorial plane. The third zone refers to particles that have gone twice or more through the equitorial plane. The positions of the zones change with time as the position of the sun with respect to the geomagnetic equator changes.

From diagram 12, one can say that if the sun is in the geomagnetic equator and emits particles of rigidities from 1 to 10 Gev. then detectors located at latitudes less than 25° would receive no new radiation. Also detectors between 25° and 30° would see an increase in counting rate, but without any strong local time dependence. Also detectors above 35° would show an increase with a maximum around 6400.

This model of Frior was successful in explaining some of the major flare effects except for two stations (Godhavn and Resolute) which according to Frior's model are outside the impact zone and yet recorded considerable increase in cosmic radiation during solar flares. In spite of the seeming success of Frior's theory it is still unable to predict why some solar flares do not produce any increase in cosmic radiation. Maybe the reason lies in the ejection mechanism during some solar flares, for up till now, it is not even known from where do these particles that arrive at the earth originate!

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