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PUBLICATION No. 91

COSMIC RAY BALLOON MEASUREMENTS AT HIGH GEOMAGNETIC LATITUDES, MARCH 1964 THROUGH JANUARY 1965

by
M. BOWTHORPE

ISSUED BY THE ANTARCTIC DIVISION
DEPARTMENT OF EXTERNAL AFFAIRS, MELBOURNE
1967

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CONTENTS

LIST OF FIGURES

PLATE

COSMIC RAY BALLOON MEASUREMENTS AT HIGH GEOMAGNETIC LATITUDES, MARCH 1964 THROUGH JANUARY 1965

By

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(Manuscript received 18 February 1966)

ABSTRACT

A series of high-altitude cosmic-ray balloon flights was carried out at Wilkes, Antarctica, during the 1964 International Year of the Quiet Sun (IQSY), in which neutron and geiger counters were flown to heights of approximately 10 g/cm^2 and floated for periods up to 44 hours. Preliminary analysis of the data shows no evidence of short-term increases of intensity of either neutrons or charged particles during 1964; the intensity versus height profiles obtained correspond to very quiet solar and geomagnetic conditions, so that reference height profiles of the unmodulated cosmic ray intensity in the vicinity of the south magnetic pole will become available.

1. INTRODUCTION

This interim report is the first of a series in which the high-altitude cosmic ray balloon programme carried out at Wilkes (geographic co-ordinates 66° 25′ S, 110° 27′ E; geomagnetic co-ordinates 78° S, 179° E), during the period March 1964 to January 1965, will be described. The work is a joint project of the Antarctic Division of the Department of External Affairs and the Physics Department of the University of Tasmania, and has been carried out under the guidance of Drs. A. G. and K. B. Fenton of that University.

The report outlines the aims of the experiments and describes briefly the instrumentation packages flown. The results of the first 9 flights are presented in graphical form in the Appendix. Later reports will similarly present the remaining flights and a discussion in detail of the results of the whole series.

II. COSMIC RAY CONSIDERATIONS

The study of cosmic rays is of fundamental interest to a number of scientific disciplines. Most of the radiation is of galactic origin, although some cosmic rays are known to be generated in the sun, and in the study of solar physics and solar-terrestrial relationships investigations of both galactic and solar cosmic rays are important. In many instances, however, investigations are made difficult because of a number of complicating circumstances which greatly influence the distribution of particles arriving at the Earth. One of these factors is that of solar modulation. Galactic cosmic rays, for example, are influenced and modulated in the solar system by solar plasma and magnetic fields before reaching the Earth. The use of neutron monitors and meson telescopes on a synoptic world-wide basis has led to a marked increase in the knowledge of modulation mechanisms and of the production of solar cosmic rays, but there remain many problems which can best be examined during a period of minimum solar activity when the modulation mechanisms are least efficient. The 1964-65 IQSY period has afforded an important opportunity for a variety of projects relating to the nature of cosmic rays and to their use as probes to investigate the nature of the geomagnetic field surrounding the Earth. Of particular interest during quiet solar conditions is the investigation of the energy spectrum of cosmic rays, especially the low-energy portion which is unable to reach the Earth at times of high solar activity.

Even during a period of low solar activity, however, cosmic ray investigations are not always straightforward. The Earth's magnetic field, for example, acts as an energy spectrometer for the low-energy portion of the primary flux; whilst this magnetic field provides an important means of analysing the energy of the incoming cosmic ray flux, it restricts the observations of low-energy particles to high latitudes.

Further, very few primary cosmic rays are able to reach the surface of the Earth because of the masking effect of the Earth's atmosphere, and most of the particles observed at sea level are of secondary origin. At an altitude of 30 km, however, only 10–20% of the primary radiation is altered by nuclear interactions with the residual atmosphere, and consequently equipment designed to observe cosmic rays at such altitudes will measure the primary radiation with relatively little secondary contamination.

III. COSMIC RAY BALLOON PROGRAMME FOR THE 1964 IQSY PERIOD AT WILKES

It is apparent from Section II that, in order to study the low-energy portion of the cosmic ray spectrum, even at times of minimum solar activity, it is desirable to carry out observations at high latitudes and high altitudes. The IQSY cosmic ray balloon programme at Wilkes was designed with the idea of monitoring the flux of low-energy charged particles and neutrons at altitudes up to 30 km and at one location near the south magnetic pole. Of particular interest are the long-term variations of the charged-particle and neutron intensities associated with the 11-year solar cycle, and the short-term variations of intensity associated with solar disturbances and short-period ionospheric and geomagnetic perturbations.

Twenty-six flights were planned to be launched throughout the year, either at regular intervals or whenever geophysical conditions were such that interesting events might be observed. Only 15 balloons were actually flown, however, due to (i) experimental difficulties in the early stages of the programme and (ii) unfavourable weather conditions during the winter months (April through August). From September 1964 to January 1965 12 balloons were flown at fairly regular intervals.

The first two flights of the series were carried out simultaneously with flights from Macquarie Island (geomagnetic co-ordinates 61° S, 243° E) and Hobart (geomagnetic co-ordinates 51° S, 229° E), and the fourth flight was made in conjunction with an extensive high-altitude cosmic ray latitude survey extending from Lae (New Guinea) to Wilkes, carried out by the Physics Department of the University of Tasmania during August and September 1964. All of these flights used near-identical equipment, similar to that designed and used by Dr. J. G. Greenhill of the University of Tasmania during his series of flights at Wilkes in 1963.

A 30 Mc/sec riometer was installed at Wilkes in April 1964 which, it was hoped, would help indicate times when balloons could be flown to their best advantage. Throughout the year, one balloon package was kept in a

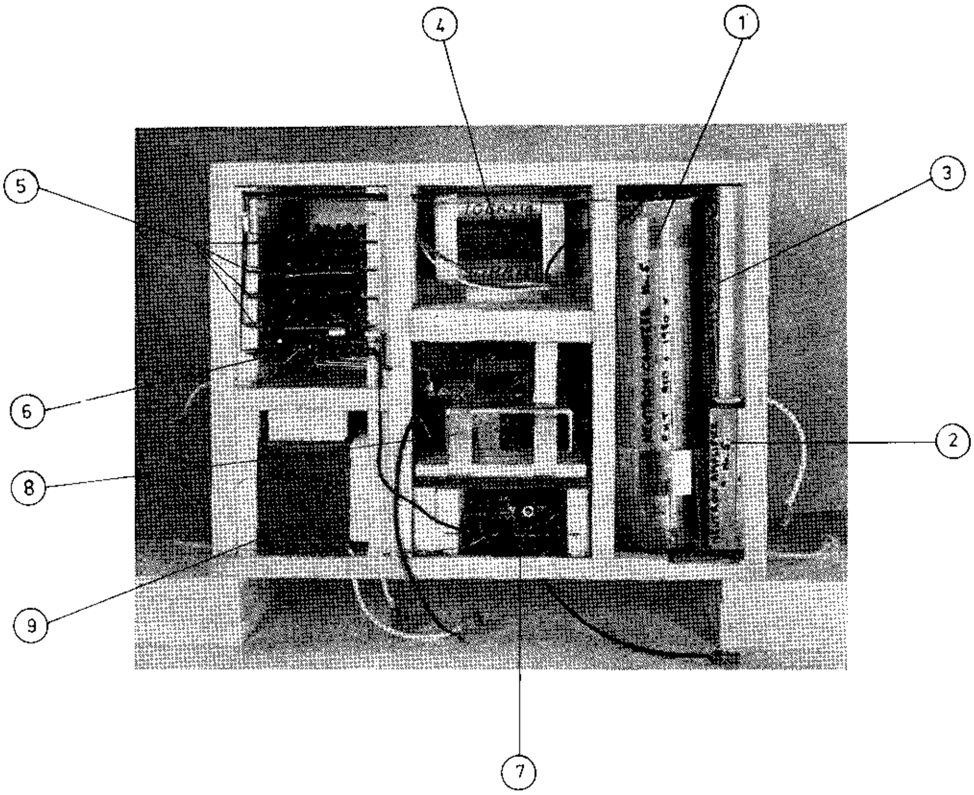


PLATE 1. Balloon flight rig.
1, Neutron counter—E.H.T. assembly; 2, neutron amplifier and discriminator; 3, neutron amplifier battery pack; 4, Geiger counters; 5, sub-carrier oscillator circuit boards; 6, mixer board; 7, transmitter; 8, baroswitch; 9, main battery pack.

state of readiness to be flown swiftly following any indication of geophysical activity shown by ground-level equipment such as the riometer, magnetometers or neutron monitor. However, no riometer absorption events were observed at Wilkes; ionosonde and magnetometer records also indicated extremely quiet geophysical conditions, and it is felt that no important cosmic ray event was missed. As a result of such quiet conditions, every effort was made to launch balloons at regular intervals on Regular Geophysical Days. Departures from this practice were usually due to unfavourable weather conditions.

So far, nine of the flight records from Wilkes have been reduced, and an analysis of the data, together with the reduction of data of the remaining flights, is currently in progress. The results of the whole series will be discussed in detail in the final report, but the following points are worth mentioning here:

(i) X-ray events detected by geiger counters at Macquarie Island during the period January to March 1964 were not observed at Wilkes; indeed it is doubtful whether X-rays were observed during any of the flights made at Wilkes.

(ii) The Wilkes data show no evidence of short-term increases of intensity of either neutrons or charged particles during 1964.

(iii) The neutron intensity at an atmospheric depth of 10 g/cm^2 at Wilkes appears to have increased by about 10% during the period January 1963 to September 1964, whereas the neutron intensity at sea level has increased by only 4·7% over the same period. Detailed results of the 1964 sea level neutron intensity have been presented elsewhere (Bowthorpe and McKenzie, 1966).

(iv) Preliminary analysis of the data from the high-altitude latitude survey shows that the neutron intensity at 10 g/cm^2 atmospheric depth during September 1964 was about ten times higher at Wilkes than at the equator.

IV. BALLOON EQUIPMENT

The balloon equipment can be divided into four main sections: the detectors, the data coding system, the mixing and the transmission systems. The data transmitted originate from a neutron counter, 2 single geiger counters, a geiger telescope and a barometric encoding device. A block diagram of the complete system is shown in Fig. 1. A brief description of the detecting and telemetry systems is given below.

A. Detectors

1. Neutron counters. The neutron counters, manufactured at the University of Tasmania under the supervision of Dr. A. G. Fenton, consist of a 1 mm-thick glass-walled envelope containing boron trifluoride enriched to 96% in the B^{10} isotope at a pressure of 45 cm of mercury. The cathode, made from 0·005 inch-thick nickel, is 20 cm in length and 5 cm in diameter; the anode is of 0·001 inch-diameter pure tungsten wire and is welded at each end to short lengths of nickel which in turn are welded to lengths of "dumet" wire passing through the ends of the glass envelope. The sensitive length of the counters is 20 cm.

Tests were carried out on each counter to obtain plots of the relative count rate versus pulse amplitude and also count rate versus counter voltage, using a radon-beryllium neutron source and standard test equipment. All counters used in the flight rigs had plateau slopes less than 1% per 100 volts over the range 1800 to 2150 volts, and during the flights operated at a stabilized voltage between 1950 and 2000 volts, depending on the individual E.H.T. supply used (cf. Section V. A).

After plateau tests had been carried out, each counter was cleaned

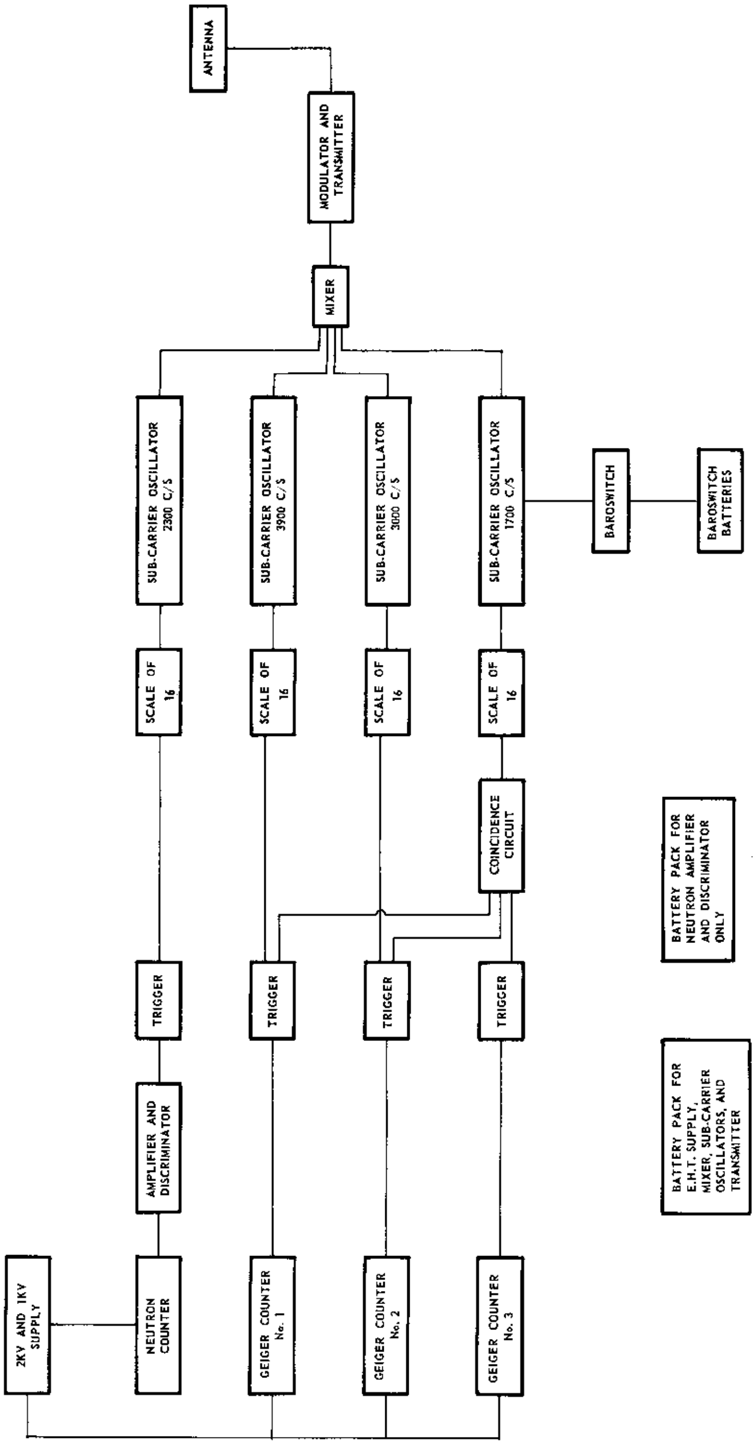


FIG. 1. Block diagram of balloon instrumentation.

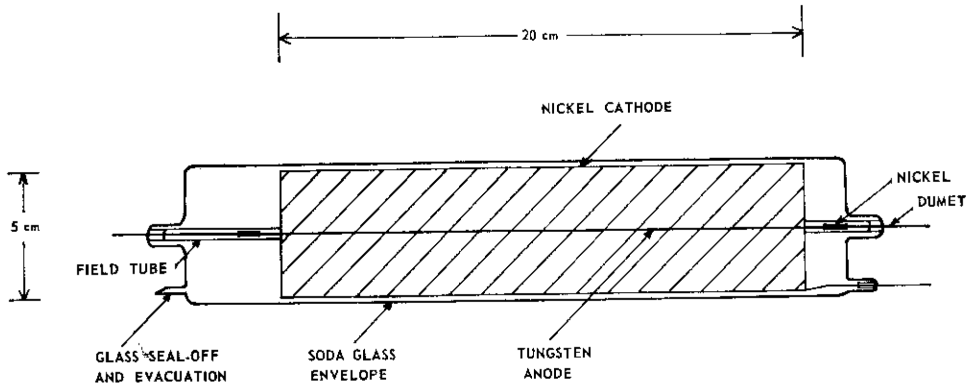


FIG. 2(a). Cross-sectional diagram of neutron counter.

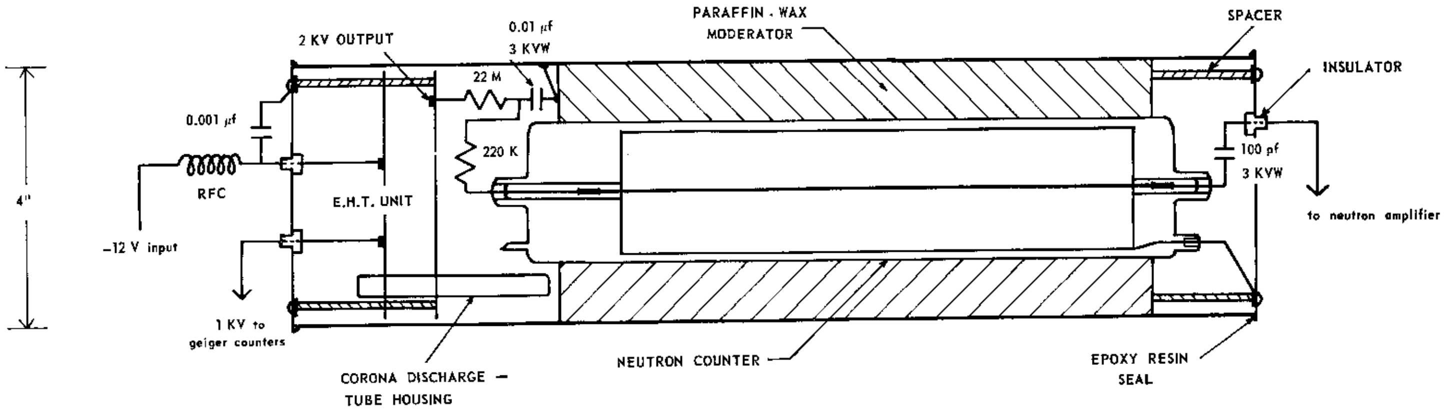


FIG. 2(b). Neutron counter—E.H.T. assembly.

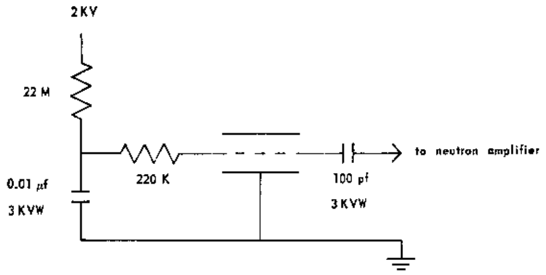
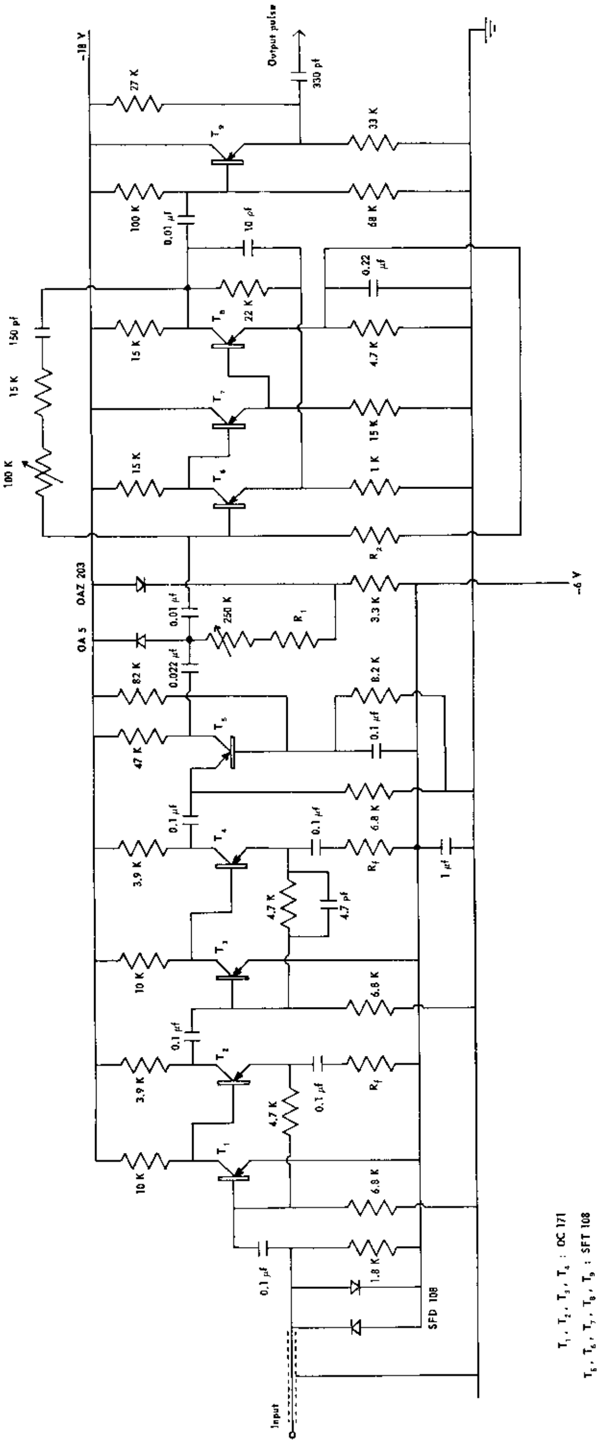


FIG. 2(c). Neutron counter circuit.

thoroughly and mounted inside a 1 inch-thick cylindrical shaped paraffin-wax moderator having an external diameter slightly less than 4 inches and length of 9 inches. The counters were held firmly inside the moderators by wrapping a few layers of thin plastic sheeting ("Visqueen") around the glass tubes. The ends of the glass envelope protruding from the moderator were lightly sprayed with "CRC 2-26" in order to reduce the electrical conductivity of the glass, and the complete unit, together with the E.H.T. supply, was mounted inside a 4 inch-diameter aluminium tube. Aluminium discs were then cemented to each end of the cylinder using an epoxy-resin so that the whole unit was completely airtight, and care was taken to ensure that no leaks could develop at the ends where input and output leads passed through the end-discs. A cross-sectional diagram of the unit is shown in Figs. 2 (a) and 2 (b).

Output pulses from the neutron counter are fed into a high-stability amplifier and pulse discriminator (cf. Fig. 3 (a)). The gain of the amplifier is approximately 120, and the discriminator is adjusted so that the output pulses are of the order of 1 volt (negative). A bias curve is obtained for the counter-E.H.T.-amplifier assembly using a Ra-Be source, and a suitable setting of the bias potentiometer chosen so that the threshold value for the counter lies centrally on the plateau of the bias curve. Since the applied E.H.T. voltage on the counter is fixed, and is on the plateau of the count-rate versus counter-voltage curve, the count-rate will be largely insensitive to equipment changes.

Each unit was then subjected to an inter-comparison calibration using a uranium-238 source built specifically for this purpose and designed to give a uniform neutron flux in all directions along the length of the counter. Care was taken to place each counter in the same position relative to the source to ensure that all were subjected to the same flux. After suitable scaling, the output pulses from the neutron amplifier were registered on a digital recorder. The whole unit was carefully shielded to eliminate spurious pulses, and each counter was calibrated for a period of between 3 and 5 hours. Inter-comparison calibration results are presented in Table 1. It will be noted that one counter (No. 1) has a much lower relative count rate than the others: this is due to the fact that a polythene sheeting



T_1, T_2, T_3, T_4 : OC 171
T_5, T_6, T_7, T_8, T_9 : SFT 108

R_f = 390 or 470 Ω
R_1 = 100 K when R_f = 390 Ω
220 K when R_f = 470 Ω

R_2 sets d.c. level in discriminator

FIG. 3(a). Neutron amplifier and discriminator.

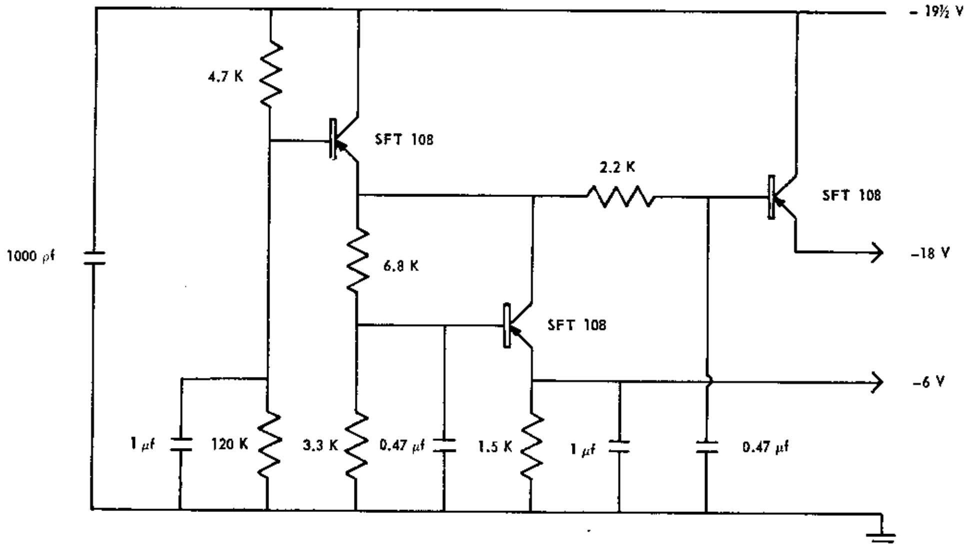


FIG. 3 (b). Battery decoupling circuit for neutron amplifier.

having a high chlorine content ("Nylex") was inadvertently used as the packing material between the counter envelope and the paraffin-wax moderator. Chlorine has a high capture cross-section for thermal neutrons, and the effect of 6 layers of 10 mil-thick "Nylex" wrapped around the counter wall, instead of the equivalent thickness of "Visqueen" polythene sheeting, was to reduce the relative sensitivity of the unit by approximately 30%.

When in the balloon rig, the neutron counter is mounted with its axis in the vertical direction.

Table 1. U^{238} intercomparison calibrations of neutron counter assemblies

Flight no.	Counter no.	Count rate (cpm)
1	1	103·3*
2	2	145·1
3	3	148·4
4	4	148·8
5	5	147·8
6	6	139·8
7	7	147·4
8	8	150·9
9	9	154·9
10	10	140·6
11	11	144·9
12	12	146·3
13	13	137·2
14	14	145·0
15	15	155·7

* With "Nylex" polythene sheeting around counter tube

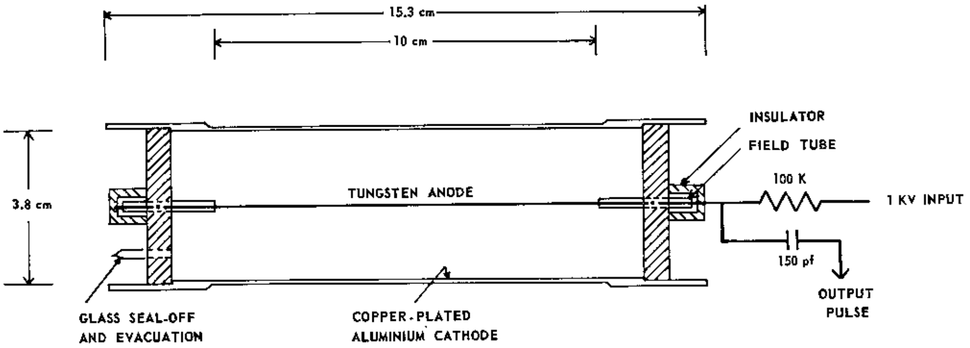


FIG. 4. Cross-sectional diagram of Geiger counter.

2. *Geiger counters.* A cross-sectional diagram of the geiger counters, manufactured at the University of Tasmania under the supervision of Drs. A. G. and K. B. Fenton, is shown in Fig. 4. The walls of the counters are of aluminium tubing machined to a thickness of 0·020 inches (± 0·003 inches), and aluminium discs are sealed onto flanges at each end. The internal walls and ends of the tubes are copper-plated, and the tubes filled with argon plus 10% butane-propane mixture at a pressure of approximately 6 cm of mercury. The anode is of pure tungsten wire 0·003 inches in diameter, welded at each end to nickel leads which pass through the end-plates of the counters. The internal diameter of the aluminium envelope is approximately 3·5 cm and the sensitive length is 10 cm.

After manufacture, plateau tests (count-rate versus operating voltage) were carried out on each counter at room temperature and at —50°C to —60°C, using a strontium-90 source. All counters performed satisfactorily at room temperature, but there was a tendency for many to break down at lower temperatures and go into continuous discharge. The unsatisfactory tubes were dismantled and replated with a slightly thicker layer of copper, and about one-half of these gave satisfactory performance when cold-tested again. The remaining counters showed satisfactory low-temperature performance only after oxidation of the copper by baking in air. Details of the performance of the individual counters are given in Table 2.

The selected operating voltage for most counters was approximately 950 volts, and the output pulses were of the order of 1 volt (negative).

In addition to their ability to detect ionising particles, the geiger counters were estimated to be about 1% efficient for the detection of X-radiation. One of the counters flown in each rig (counter B) was surrounded by a 0·004 inch-thick iron foil; the energy losses for X-rays in the unshielded and shielded counters were 25 kev and 40 kev respectively.

3. *Geiger telescopes.* In addition to the single geiger counters A and B, a 3-fold vertical-pointing coincidence telescope consisting of counters A, B and C was used on several occasions. On other occasions, however,

counter C was not used, and counts were recorded from the single counters A and B and from the 2-fold coincidence telescope AB only. The geometry of the 3-fold telescope is shown in Fig. 5. The extreme angle of acceptance is approximately 53°, although the effective extreme angle is undoubtedly larger, due to scattering and secondary production above the telescope.

The telescopes were made from individual counters having comparable starting voltages (to within 10 volts) and comparable plateau slopes. Unfortunately, it was not possible to calibrate the telescopes in Hobart prior to departure for Wilkes, due to the limited time available; most 3-fold coincidence telescopes, however, were calibrated at Wilkes for periods of 24 hours, using the natural cosmic ray background as a source, and one of these telescopes was returned to Hobart to be re-calibrated, using a standard source.

B. Balloon telemetry system

The telemetry system used for the cosmic ray balloon experiments has been described elsewhere (Greenhill, 1966). However, a brief description will be given here for completeness.

1. Data coding system. The data coding system consists of 4 modulators and sub-carrier oscillators. A transistor-switch modulator is used which helps preserve the full sub-carrier deviation, but which inherently limits the amount of information which can be put onto any one channel to one set of modulations only. The oscillators operate on the standard IRIG frequencies of 1·7 kc, 2·3 kc, 3·0 kc, and 3·9 kc, and are frequency-modulated. Channel allocation of the various detectors in the rig is as follows:

Geiger counter A (unshielded)	3·9 kc
Geiger counter B (shielded)	3·0 kc
Neutron counter	2·3 kc
Geiger telescope AB or ABC, plus baroswitch	1·7 kc

The frequency deviation of each oscillator is approximately $\pm 6\frac{1}{2}\%$.

The modulator input signals are square waves from a scale-of-sixteen binary system preceding each sub-carrier oscillator, and the modulator is reasonably linear over the standard $\pm 7\frac{1}{2}\%$ bandwidth.

The capacitor C_2 in Fig. 6 (d) is essentially responsible for controlling the output frequency of the oscillator, and final tuning is accomplished by adjustment of the slug in the inductance L. The coil consists of 2860 to 2900 turns of 40 B and SP "Posyn" wire wound onto a D25/16 pot core bobbin, and this is fitted onto a Q-plus USW2 unwound coil former. The slug gives an overall frequency adjustment of approximately 15%, and the same type of coil is used for all sub-carrier oscillators. The distribution of additional switched capacity (C_3 in series with C_4) between C_3 and C_4 was adjusted to maintain equal output amplitudes in the 2 oscillator

TABLE 2. Geiger counter and telescope calibration data

Flight No.	Telescope		Counters		Test temperature (°C)	Starting voltage (volts)	Plateau slope in range 900 to 1000 volts (% per 100 volts)	Sr^{90} count rate (cpm)	Telescope calibration (cpm)†
	No.	Type							
1	1	3-fold	A	Top					
			B*	Middle					
			C	Bottom					
2	2	2-fold	A	Top	—51 A	860	2·9	12 028	
			B*	Bottom	—55 O	870	2·6	10 590	
3	3	3-fold	A	Top	—62 R	870	3·0	9 720	
			B*	Middle	—58 A	870	2·0	9 300	
			C	Bottom	—54 O	870	5·2	10 862	
4	4	3-fold	A	Top	—55 O	870	2·0	11 172	
			B*	Middle	—55 O	870	1·5	10 356	
			C	Bottom	—57 O	870	4·8	10 696	
5	5	2-fold	A	Top	—55 O	870	5·3	9 982	
			B*	Bottom	—55 A	870	5·0	9 320	
6	6	2-fold	A	Top	—58 R	870	3·9	10 282	
			B*	Bottom	—52 A	870	3·8	9 794	
7	7	2-fold	A	Top	—53 A	880	4·0	10 760	
			B*	Bottom	—55 A	880	5·0	9 916	
8	8	2-fold	A	Top	—56 O	870	4·2	10 594	
			B*	Bottom	—55 R	870	4·0	10 498	
9	9	2-fold	A	Top	—58 O	840	6·0	11 030	
			B*	Bottom	—52 A	850	6·5	10 476	
10	10	2-fold	A	Top	—58 A	870	4·0	10 626	
			B*	Bottom	—58 A	870	4·0	10 268	
11	11	3-fold	A	Top	—53 A	860	3·5	9 616	8·5
			B*	Middle	—59 R	860	3·7	9 556	
			C	Bottom	—51 R	860	3·0	10 206	

12	12	3-fold	A Top	—51 R	870	5·5	12 396	8·2
			B* Middle	—57 R	870	5·0	10 118	
			C Bottom	—57 O	880	6·6	11 198	
13	13	3-fold	A Top	—62 R	870	4·5	10 536	9·2
			B* Middle	—54 O	870	4·5	10 298	
			C Bottom	—51 R	875	3·5	12 226	
14	14	3-fold	A Top	—54 O	870	6·0	10 552	9·1
			B* Middle	—52 A	870	6·7	10 260	
			C Bottom	—58 A	870	4·0	10 474	
15	15	3-fold	A Top					9·7
			B* Middle					
			C Bottom					

* Counter with iron foil shielding.

† Source—natural cosmic ray background at fairly constant sea-level pressure.

Notes on cold-testing:—
A—refers to counters passing cold test on first attempt.
R—refers to counters passing cold test only after replating with thicker layer of copper.
O—refers to counters passing cold test only after oxidation of the copper by baking in air.

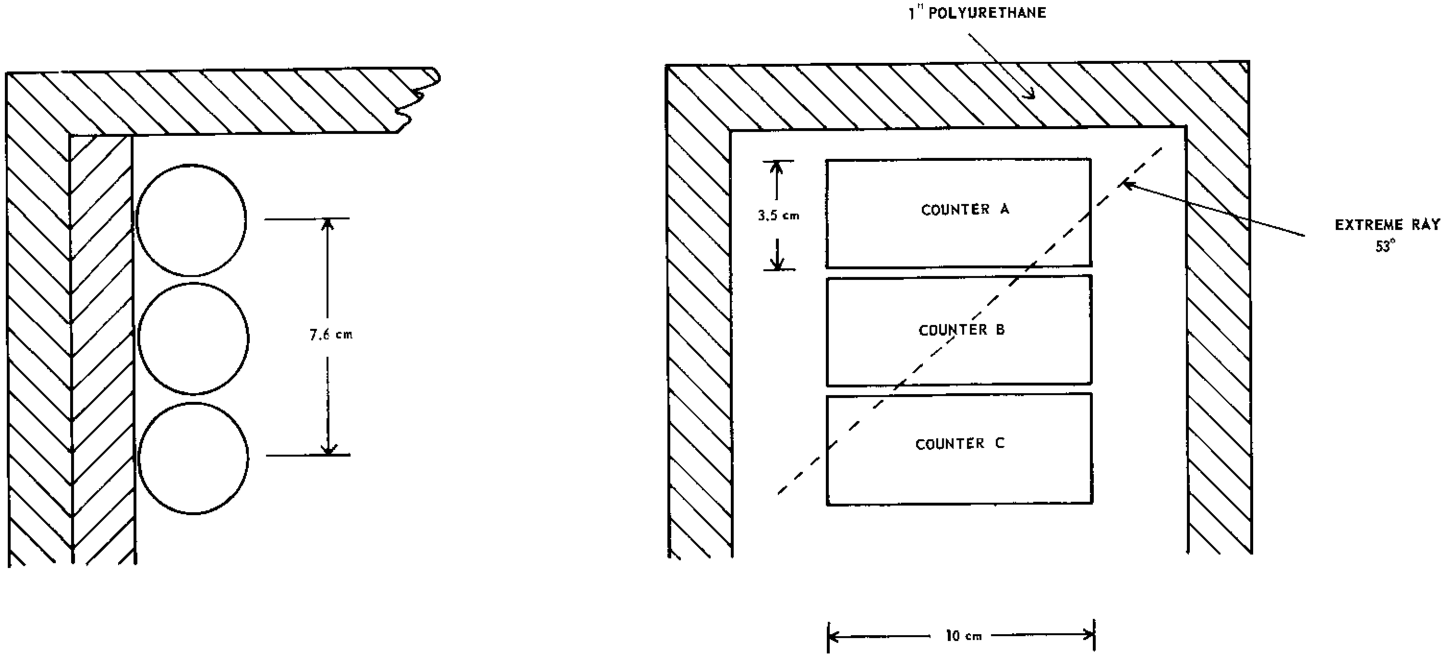


FIG. 5. Geometry of 3-fold coincidence telescope.

states. The output voltages vary from 0·25 volts peak-to-peak for the 1·7 kc oscillator to 0·5 volts peak-to-peak for the 3·9 kc oscillator.

The 1·7 kc oscillator has an additional capacitor (C_6) which is paralleled across C_2 by the "closing" of the baroswitch. The effect of the additional capacitance is to produce a 4% decrease in carrier frequency; the total frequency deviation between the high state (with baroswitch "open") and low state (with baroswitch "closed") is approximately $\pm 6\frac{1}{2}\%$. Further, in the case of the 1·7 kc channel, a coincidence circuit is used before the first binary stage, so that only particles passing through all geiger counters "simultaneously" are recorded. The resolution of the coincidence circuit is about 4 microseconds.

The coincidence circuit, binaries, modulators and oscillators operate from a stabilized —6-volt supply employing a zener diode. The —12-volt input for the stabilized supply is obtained from the main battery pack, and it is possible to maintain full binary collector swing, and consequently positive switching of the sub-carrier modulator, even when the battery volts fall considerably. Polyester capacitors are used in most of the circuits, particularly in the oscillators, and virtually no change in amplitude nor drift in frequency is observed at low temperatures.

2. Mixing system. The mixer consists of a very linear amplifier with four inputs (one for each sub-carrier oscillator). Four common-collector amplifiers are used to drive a common-base amplifier. Mixing is accomplished at a low impedance level and very little distortion and cross-talk occurs. The input resistors R_1 to R_4 (Fig. 7) are adjusted such that the mixer outputs of the individual sub-carrier oscillator inputs are in the ratios of approximately 1 : 1·6 : 2·3 : 3·4 for the 1·7 kc, 2·3 kc, 3·0 kc and 3·9 kc oscillators respectively. The total linear output swing of the mixer is about 8 volts peak-to-peak.

3. Transmission system. The transmission system consists of a frequency-modulated power oscillator using a 2N707 power transistor. The transmitter is basically a common-base oscillator, the main difference from the conventional circuit being the grounding of the collector instead of the base. Feedback is applied to the emitter-base junction, and the output is taken from the collector-base junction. The transistor is mounted rigidly in a small aluminium heat sink which is secured to the copper-plate chassis.

The transmitter layout is not very critical, but it is desirable to have short leads in the tank circuit. The tank coil consists of $1\frac{1}{2}$ turns of no. 16 wire wound on a $\frac{3}{4}$-inch diameter, and the tap for matching into a 72-ohm load is placed $\frac{3}{4}$ turns from one end. With 18 volts supplied to the base circuit, the transmitter output varies from 130 mw to 200 mw at 86 Mc/sec; these values vary with individual transistors and layouts. Higher supply voltages will result in higher output power if required. A 150-ohm resistor in the emitter circuit limits the transistor current to 35-40 milliamps.

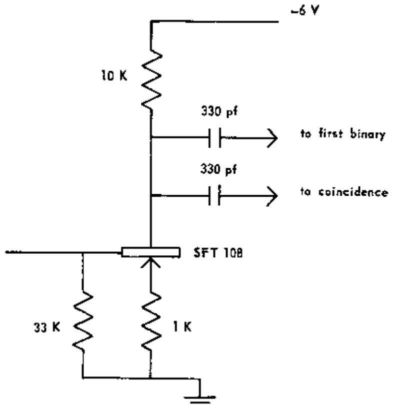


FIG. 6(a). Trigger circuit.

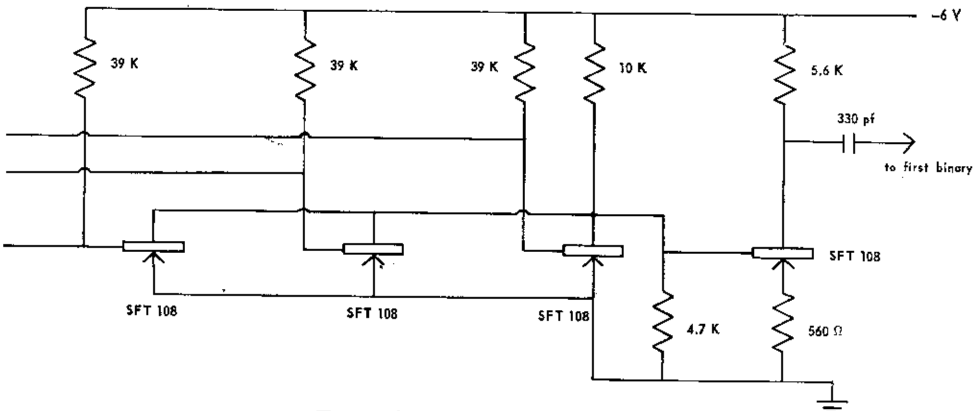


FIG. 6(b). Coincidence circuit.

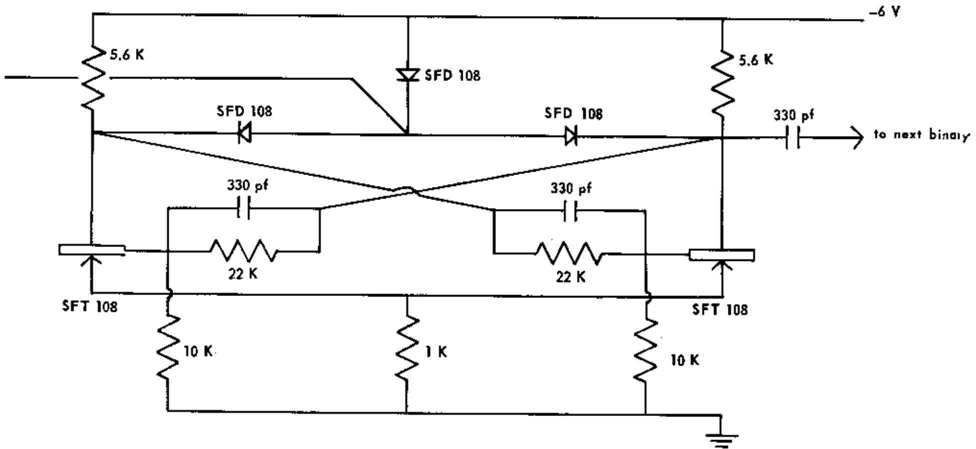
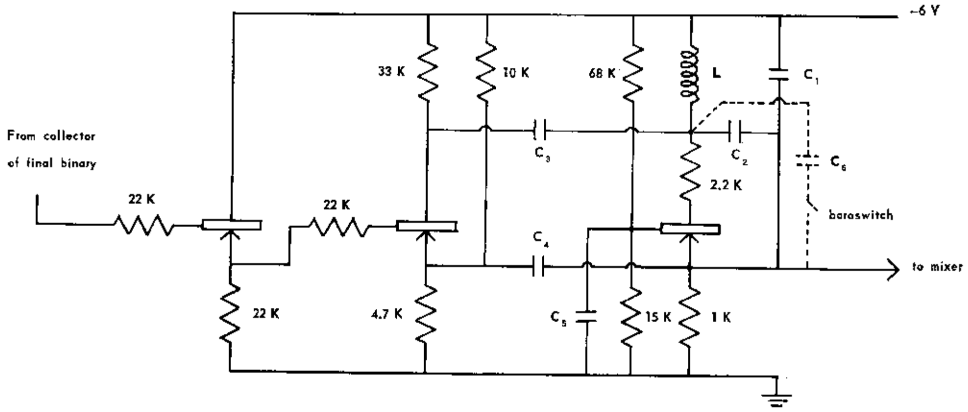


FIG. 6(c). Binary circuit.

Shielded cable is used in the audio-signal line from the mixer to transmitter, and the transmitter is shielded by placing it in a metal can within the rig.

The antennas used on all flights were horizontal turnstiles, although the transmitter will operate well with other types.

In a few cases, the transmitters proved somewhat difficult to align



(All transistors – SFT 108)

FREQUENCY (c/sec)	C_1	C_2	C_3	C_4	C_5	C_6	L (mh)
1 700	1.0 μf	0.1	0.033	0.22	0.27	0.01	~ 100
2 300	0.47	0.056	0.022	0.22	0.22	–	~ 100
3 000	0.22	0.033	0.022	0.1	0.22	–	~ 100
3 900	0.22	0.022	0.01	0.056	0.22	–	~ 100

All capacitances in μf

FIG. 6(d). Modulator and sub-carrier oscillator.

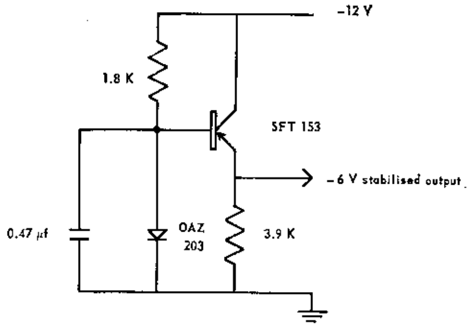
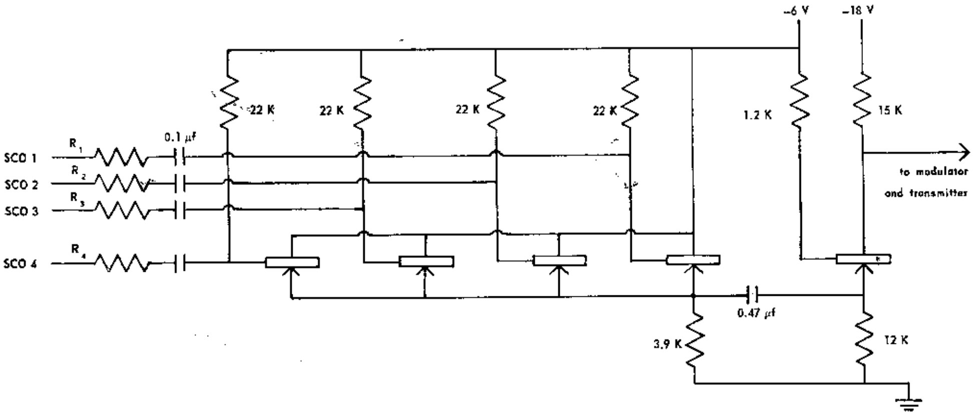


FIG. 6(e). Stabilized six-volt supply.

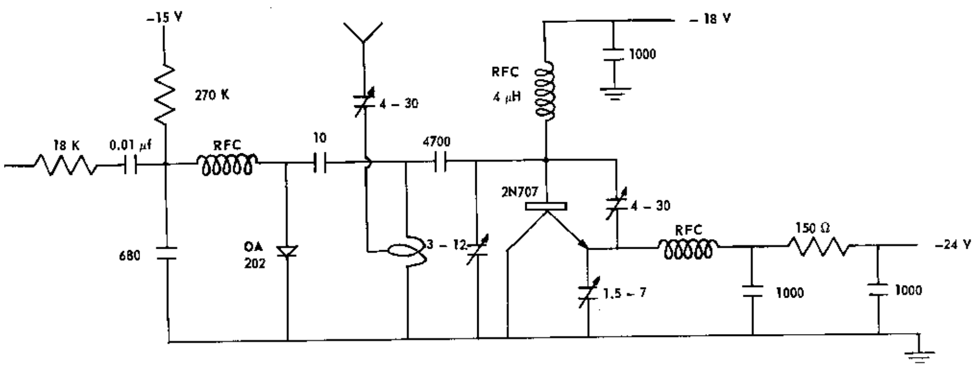
for maximum power at the desired frequency, although, once aligned, usually remained very stable and drifts in frequency were negligible. Strong reflections at 92-94 Mc/sec, and occasionally at 72 Mc/sec also were often observed when setting up the transmitter on the ground at Wilkes, but these became very weak when the rig was taken about 200 yards away from the receiver, and were undetectable once the rig became airborne.

Circuits diagrams of the telemetry system are given in Figs. 6 (a to e), 7 and 8.



All transistors - SFT 153

FIG. 7. Mixer circuit.



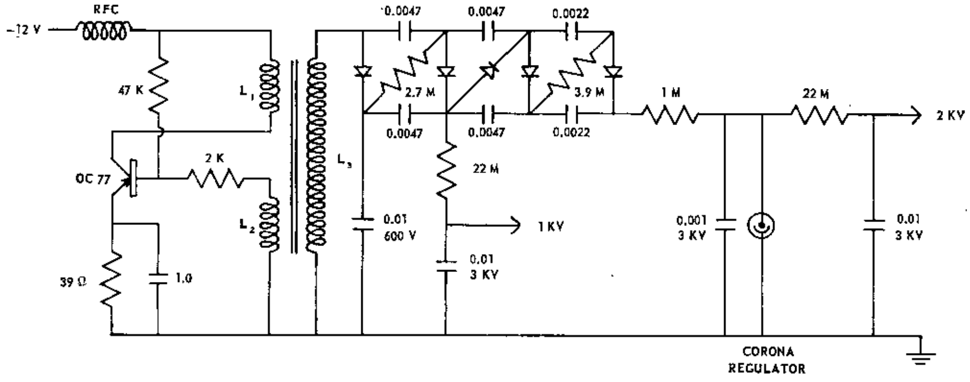
All capacitances in pf unless stated otherwise

FIG. 8. Modulator and transmitter.

V. AUXILIARY EQUIPMENT

A. E.H.T. supply

The E.H.T. provides a nominal 900-volt unregulated supply for the geiger counters and 2000-volt regulated supply for the neutron counter. In practice, these values ranged from 890 to 925 volts and 1900 to 2000 volts respectively from board to board. However, for any one board the output voltages varied by less than 5 volts when the input voltage was reduced from —12 volts (at room temperature) to —6 volts (circuit sprayed with circuit-cooler). For a counter having a plateau slope of 4% per 100 volts, the change in counting rate due to changes in the supply voltage is less than 0·2%.



Diodes – OA 211

All capacitances in µf

L_1 : 450 turns of 38 B & S wire
L_2 : 100 turns of 38 B & S wire
L_3 : 4500 turns of 40 B & S wire

FIG. 9. E.H.T. supply.

A circuit diagram of the E.H.T. supply is given in Fig. 9. The unit is mounted on two 4-inch diameter circular matrix boards, and fits into one end of the aluminium tube containing the neutron counter (cf. Fig. 2 (b)).

B. Baroswitches

As the experiments require that the balloon and payload should float at a fixed altitude, the use of the standard meteorological baroswitch may lead to ambiguous results, since once the balloon has approached floating altitude, a change in baroswitch contact will not always indicate whether the balloon has risen or fallen. This ambiguity has been resolved to a large extent by incorporating a third set of contacts onto the commutator strip of a standard baroswitch such that, at altitudes above approximately 20 millibars, a change in contact will indicate unambiguously whether the balloon has risen or fallen. Some ambiguity still exists due to the finite width of the contacts and spacings between contacts, but the error arising from this is smaller than the error expected in the baroswitch at these pressures.

When this type of baroswitch is used, three additional capacitors are included on the 1·7-kc oscillator board. The action of the aneroid cell arm when touching a contact is to switch one of these three capacitors in parallel with C_2, thereby shifting the carrier frequency by 1%, 2½% or 4% towards lower frequencies.

A second type of baroswitch (manufactured by A. Sprenger Co., West Germany), in which the commutator strip is replaced by a rotating drum on which the contacts have been etched, was also used on several flights. The pressure readout is in the form of a series of dots and dashes, and readings are obtained for each rotation of the drum (approximately three times per minute when the motor is driven from a 4½-volt battery). Any rise or fall of the balloon is at once evident.

The baroswitch contains two aneroid cells, one of which operates from 1100 mb to 30 mb, and the other (more sensitive cell) from 200 mb to 4 mb. In practice, it was found that, at pressures below 200 mb, the two aneroid cells differed in their pressure readouts by as much as 10 mb. On several flights made from Wilkes, however, a standard meteorological radiosonde was attached to the balloon; in all cases, the Sprenger baroswitch agreed well with the Bendix-Friez meteorological baroswitch between ground-level and 200 mb, and between 180 mb and 5 mb. In the region of 200 mb to 180 mb, correlation could be obtained if a gradual uniform transfer was made from one cell to the other of the Sprenger baroswitch, and this procedure was adopted for obtaining the pressure in this region whenever Sprenger baroswitches were flown.

A temperature-measuring device employing a bi-metallic strip is also incorporated in the baroswitch, and temperature readings down to —65°C may be obtained if necessary.

RF interference from the baroswitch motor was virtually eliminated by shielding the baroswitch in a metal can and by using rf chokes and by-pass condensers in the leads to the 1·7 kc sub-carrier oscillator.

C. Battery packs

The main battery pack supplies power to the sub-carrier oscillator boards (viz. trigger, coincidence, binaries, modulator and oscillator circuits) via the emitter-follower zener diode stabilized supply, and to the mixer, E.H.T. supply and transmitter. A second pack supplies power to the neutron amplifier and discriminator although, on occasions, power for this has been obtained from the main pack via a decoupling circuit in order to minimize weight.

The main pack was made from a combination of "Eveready" E95 (D-size) and E94 (½D-size) 1½-volt alkaline manganese cells supplying a total of 24 volts. The number of each type used depended on the expected duration of the flight; 16 E94 cells were adequate for flights lasting less than about 8 hours, whilst 12 E95's (0-18 volts) and 4 E94's (18-24 volts) enabled data to be transmitted for more than 36 hours. Many (∼40%) unused batteries were rejected before flying due to leakage of the alkaline and to open-circuiting within the battery, but those accepted performed well, even at the lowest temperatures (∼ —55°C) encountered.

The current drain from the battery pack is as follows:

— 24 volts	35 — 40 ma for transmitter only
— 18 volts	< 1 ma for transmitter 0·5 ma for mixer
— 12 volts	∼ 38 ma for E.H.T. supply and emitter-follower stabilized supply for s/c oscillator boards
— 6 volts	1·2 ma for mixer only.

The neutron amplifier battery pack consists of 12 "Eveready" E91 1½-volt alkaline cells, with outputs at —6 and —18 volts. Current drain is 6 ma at —18 volts.

Three E91 batteries are used to drive the motor of the Sprenger baroswitch.

Transmitter modulator bias is provided by an "Eveready" 15-volt "Mini-max" cell.

VI. RIG LAYOUT

A photograph of the complete rig is shown in Plate 1. The detectors, circuit boards, etc., fit inside a box of 1 inch-thick white polyurethane foam measuring 7 inches × 18½ inches × 24½ inches, and the total weight of the rig (including batteries and antenna) is about 18 lb.

After the final testing of each section, the front panel of the rig is taped into position, and the rig placed in a cotton harness which ensures accurate level support. Leads from the batteries to the mixer/sub-carrier oscillator boards, transmitter and neutron amplifier, and also to the motor of the Sprenger baroswitch, pass through the sides of the rig, and are connected just prior to launch.

VII. BALLOONS

The cosmic ray balloon programme required that the instrumentation packages be flown to altitudes of approximately 10 g/cm^2 and float in that region for as long a period as possible. A number of "constant-floating-level" polythene balloons (volume: 58,000 cu ft, manufactured by Raven

TABLE 3. Rig and balloon performance

Date	Flight No.	Duration (UT)	Type of balloon	% free lift	Payload (lb)	Maximum altitude (g/cm²)	Time to reach max. altitude	Comments	Cause of termination of flight
1964									
2 Mar.	1	1119-1434	Polythene	25·0	19·31	8	2hr 13m	All channels good	E.H.T. failure due to leak in neutron counter assembly
7 Mar.	2	1152-1812	Polythene	25·0	17·35			All channels good but no pressure data	Balloon out of range
18 Mar.	3	0512-1213	Polythene	30·0	20·28	10	2hr 06m	40 minutes neutron data lost during ascent; all channels good otherwise	Balloon out of range
20 Sept.	4	0435-0708	Neoprene (J11-28-2400)	16·5	20·91	6	2hr 11m	All channels good	Balloon out of range
27 Sept.	5	0915-1306	Neoprene (J11-28P-2400)	17·2	16·81	50	3hr 28m	All channels good. Very slow rate of ascent above 120 g/cm^2	Balloon out of range
2 Oct.	6	0844-1130	Neoprene (J11-28P-2400)	16·4	18·84	36	1hr 59m	3·9kc channel noisy throughout flight; all other channels good	Balloon out of range
7 Oct.	7	0849-1106	Neoprene (J11-28P-2400)	13·8	18·50	18	2hr 14m	All channels good	Balloon out of range
17 Oct.	8	0208-0419	Neoprene (J11-28-2400)	16·4	16·08			3·9kc channel noisy at times, and pressure data unsatisfactory; all other channels good	Balloon out of range
21 Oct.	9	0604-0805	Neoprene (J11-28P-2400)	14·0	17·84	137	1hr 09m	All channels good	Premature burst at 137 g/cm^2; data obtained to 450 g/cm^2 on descent

28 Oct.	10	0350-0630	Neoprene (J11-28-2400)	20·0	17·88			1·7kc channel noisy, resulting in loss of pressure data; 2·3kc channel noisy at times. All channels noisy in latter part of flight due to local RF interference	Signals noisy due to local RF interference
15, 16 Nov.	11	1716 (15th) to 0932 (16th)	Polythene	25·0	19·38	10	3hr 55m	All channels good. Very slow rate of ascent above 100 g/cm^2	Balloon out of range
27, 28 Nov.	12	1246 (27th) to 1558 (28th)	Polythene	30·0	17·81	8	2hr 15m	All channels good	Battery voltages low after 27 hours. Balloon not out of range
15, 16, 17 Dec.	13	2241 (15th) to 1901 (17th)	Polythene	35·0	19·88	11	2hr 15m	No neutron data for 32 hours during flight; no pressure data for last 24 hours of flight; all other channels good	Battery voltages low after 44 hours. Sub-carrier boards stopped operating although transmitter still working. Balloon not out of range
1965 2, 3 Jan.	14	2136 (2nd) to 1756 (3rd)	Polythene	35·0	26·51	10	2hr 10m	1·7kc channel noisy for 30 minutes during ascent and for 2 hours at end of flight; all other channels good	Signals weak after 20 hours but balloon still overhead
18, 19 Jan.	15	0034 (18th) to 0937 (19th)	Polythene	35·0	20·12	15	1hr 52m	No neutron data for 8 hours during flight; no pressure data for last 16 hours of flight. Occasional RF interference from ship-to-shore radio. All channels good otherwise	Battery voltages low after 33 hours. Balloon not out of range

Industries Inc.) were purchased, and the programme was supplemented by the use of several "Darex" 2400 gm extensible neoprene balloons (types J11-28-2 400 and J11-28P-2 400 manufactured by Dewey and Almy Pty. Ltd.).

Polythene balloons were used whenever wind conditions were such that data could be obtained for a period of 8 hours or more. A method of floating the neoprene balloons at high altitudes, using a modification of the valve technique developed by Hopper and Laby (1960), was arranged for the Darex balloons, and a number of valves were made for this purpose. The valves were not used, however, since neoprene balloons were flown only during the September-October period when high-altitude winds were often in excess of 180 km/hr; in most cases the balloons were out of telemetry range within a few hours, often before bursting altitude was reached.

The performance of the polythene balloons proved to be highly reliable and, despite some difficulties experienced in handling in winds exceeding 20 km/hr, were comparatively easy to launch with a limited amount of assistance. A floating altitude of 10-12 g/cm^2 was achieved by most balloons, and with 30% free lift would reach this altitude within 2 hours.

The neoprene balloons were treated in a humidifier for several hours before flying, and generally performed well. Parachutes were attached to the rigs carried by these balloons so that data could be obtained during descent in the event of a premature burst. Premature bursting (at 137 g/cm^2) occurred on one occasion only, and data was obtained for a large portion of the descent stage of the flight.

Details of the rig and balloon performances are presented in Table 3.

VIII. GROUND TELEMETRY SYSTEM

The telemetry equipment used was that left at Wilkes by Dr. J. G. Greenhill after his series of flights in 1963 (Greenhill, 1966), and will not be described here in detail. A block diagram of the system is shown in Fig. 10; the system is completely transistorised and operates from a 12-volt batttery supply. The 240-volt 50-c/sec supply for the pre-amplifier power supply, tape recorders and chart recorder is obtained from a 12/240-volt transverter and 50-c/sec synchronous amplifier, the 50-c/sec signal being obtained from the crystal clock.

The rotatable antenna system, consisting of a stacked pair of 5-element yagis, was mounted on a hill near the cosmic ray laboratory, and was controlled from within the laboratory. The FM receiver output is played directly onto magnetic tape, and also onto paper chart (using a 4-channel "Both" oscillograph) after suitable amplification, filtering and discriminating, etc. Provision is also made to record signals onto an "event" recorder, using a variety of convenient scaling factors; unfortunately, the event recorder was unserviceable and could not be used. One-second and

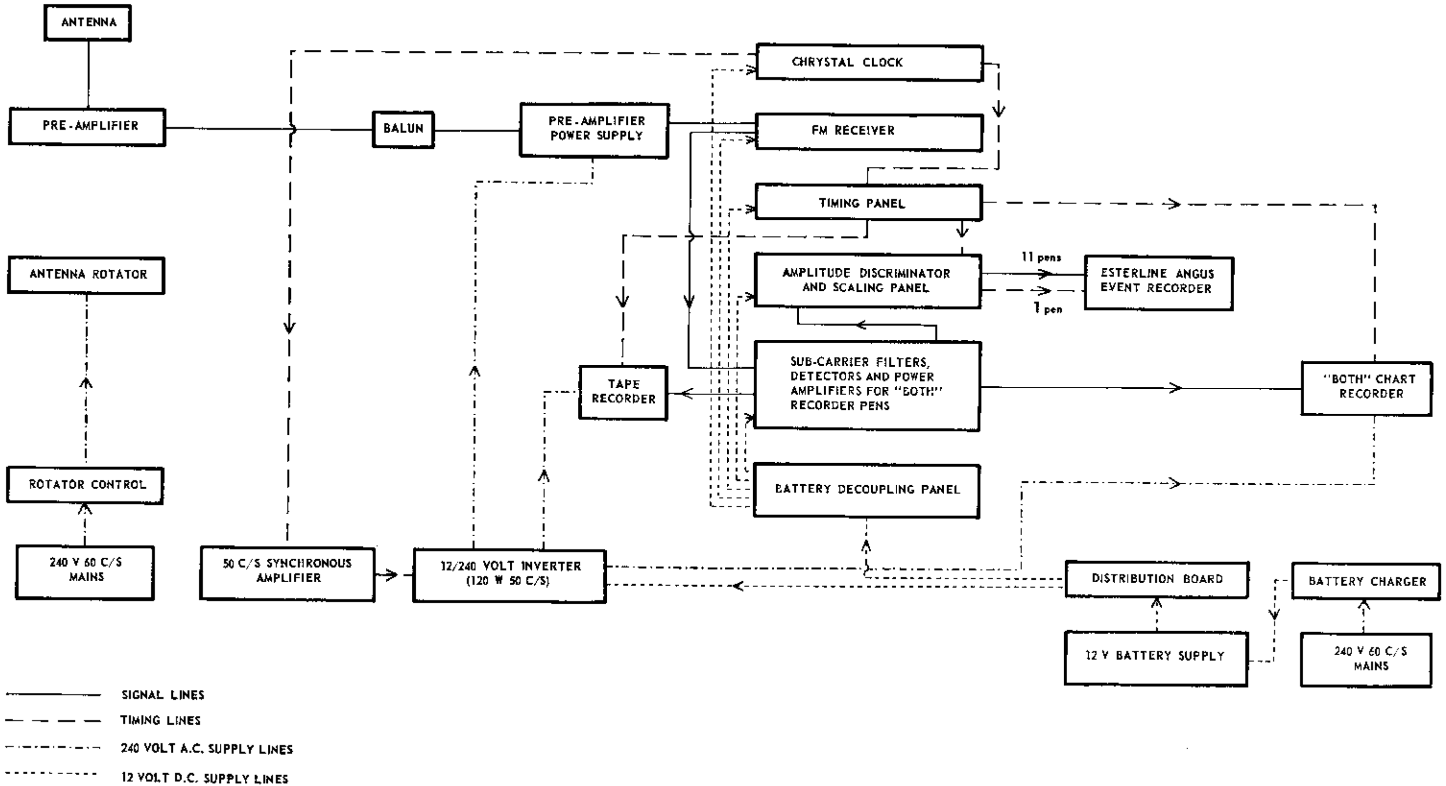


FIG. 10. Block diagram of ground telemetry system.

one-minute timing pulses are fed onto the tape and paper-chart recorders from the crystal clock via the timing panel.

The telemetry system at Wilkes did not have any form of digital readout, but a digital readout panel has been included in a similar telemetry system at Hobart. Magnetic tapes on which original flight data have been stored can be replayed into the telemetry and timing panels (replacing the direct receiver and crystal clock inputs respectively) and it is by this method that most of the data from the 1964 Wilkes flights have been reduced to date.

IX. ACKNOWLEDGEMENTS

The author wishes to thank those members of the Physics Department, University of Tasmania, who assisted in the construction and assembly of counters and associated electronic circuitry, and Drs. A. G. Fenton, K. B. Fenton and J. G. Greenhill who gave invaluable advice in connection with the project. Particular thanks are expressed to Mr. G. A. Smith (Senior Electronics Technician) for his assistance in all phases of the balloon programme both at Hobart and at Wilkes, and for his assistance in installing and operating the riometer at Wilkes. The author is also indebted to members of the 1964 Wilkes party who gave assistance in launching the balloons, often under difficult circumstances.

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GREENHILL, J. G. (1966). Ph. D. thesis, University of Tasmania.

HOPPER, V. D., and LABY, J. E. (1960). High altitude studies with meteorological balloons. *Beitr. Phys. Atmosphaere*, Vol. 32, p. 237-48.

APPENDIX

GRAPHICAL PRESENTATION OF DATA

FLIGHTS 1 to 9

(FIGS. 11 to 45)

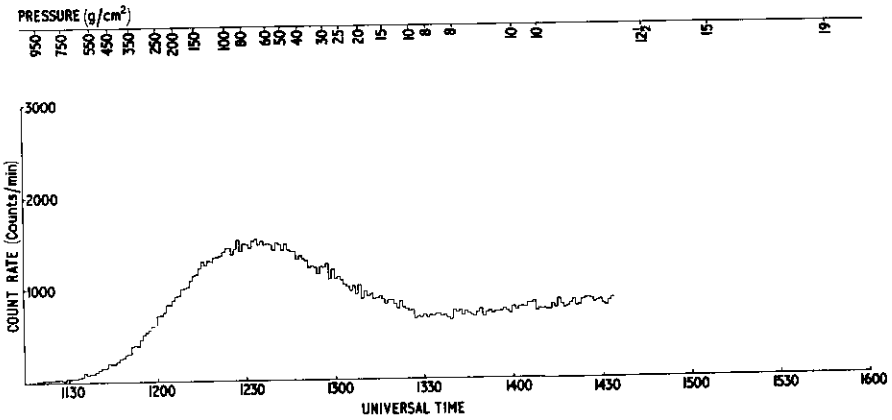

FIG. 11. Neutron count rate, Flight 1, 2 March 1964.

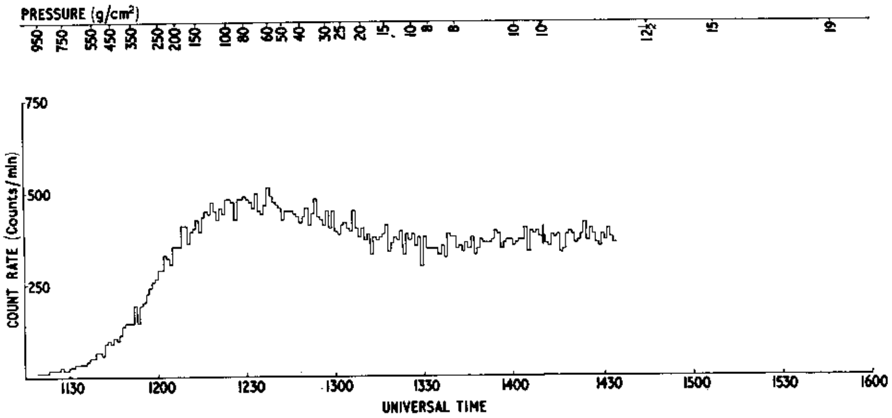

FIG. 12. Triple coincidence count rate, Flight 1, 2 March 1964.

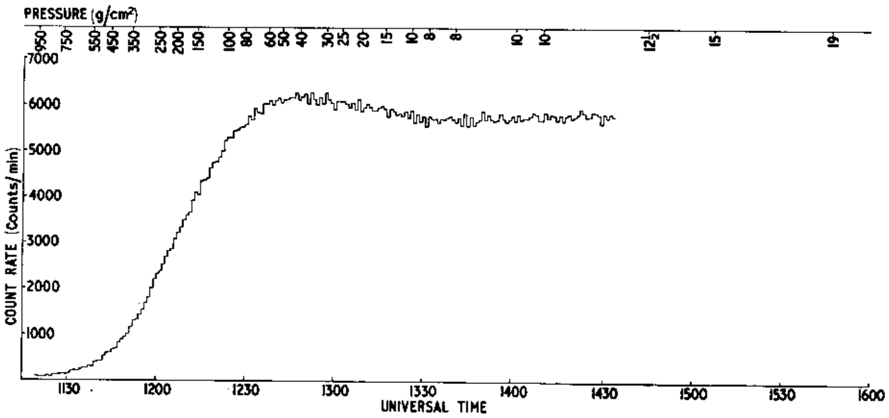

FIG. 13. Geiger (unshielded) count rate, Flight 1, 2 March 1964.

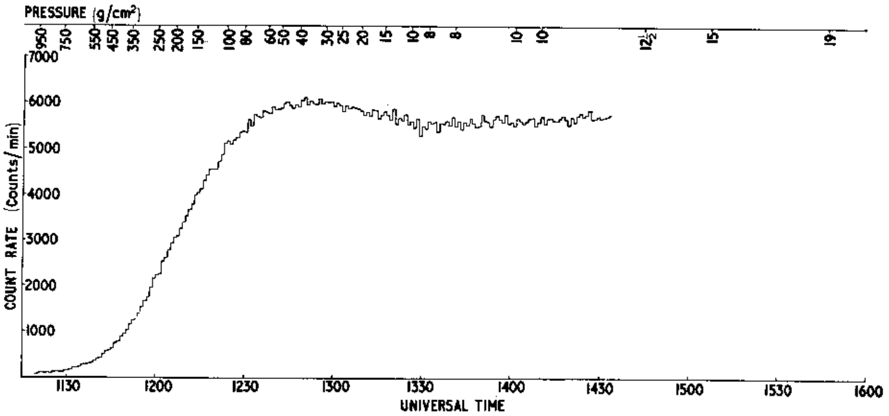

FIG. 14. Geiger (shielded) count rate, Flight 1, 2 March 1964.

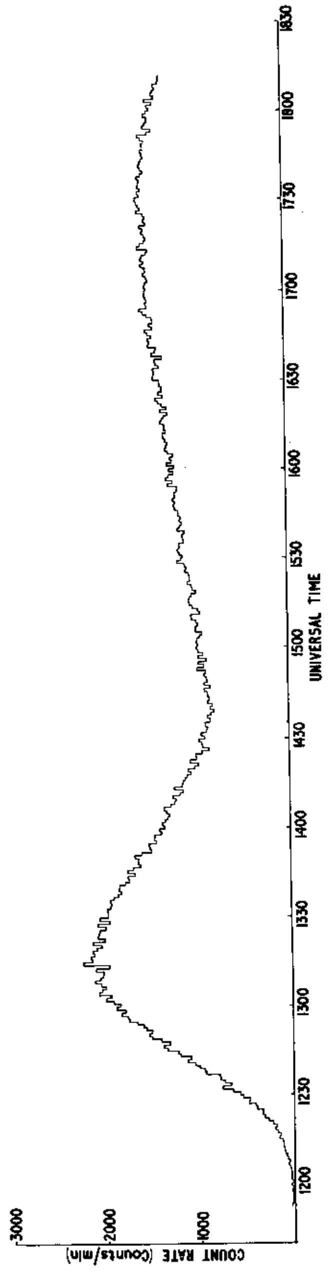

Fig. 15. Neutron count rate, Flight 2, 7 March 1964.

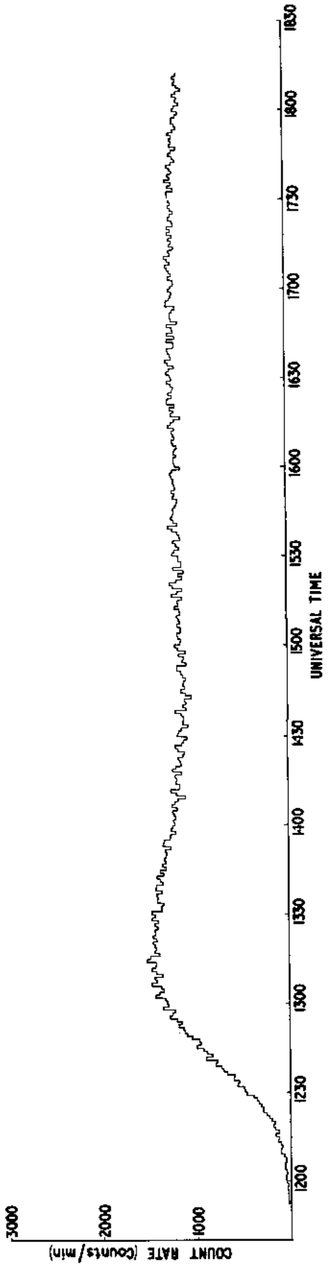

Fig. 16. Double coincidence count rate, Flight 2, 7 March 1964.

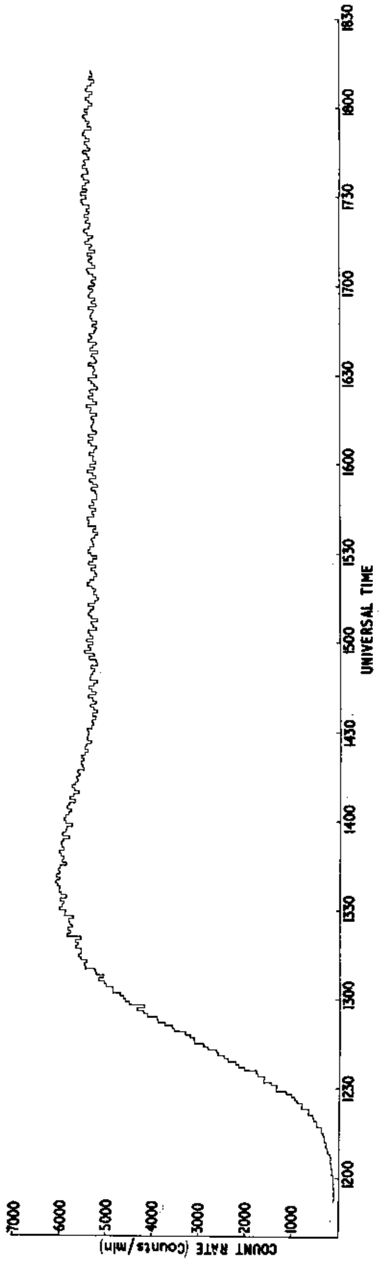

FIG. 17. Geiger (unshielded) count rate, Flight 2, 7 March 1964.

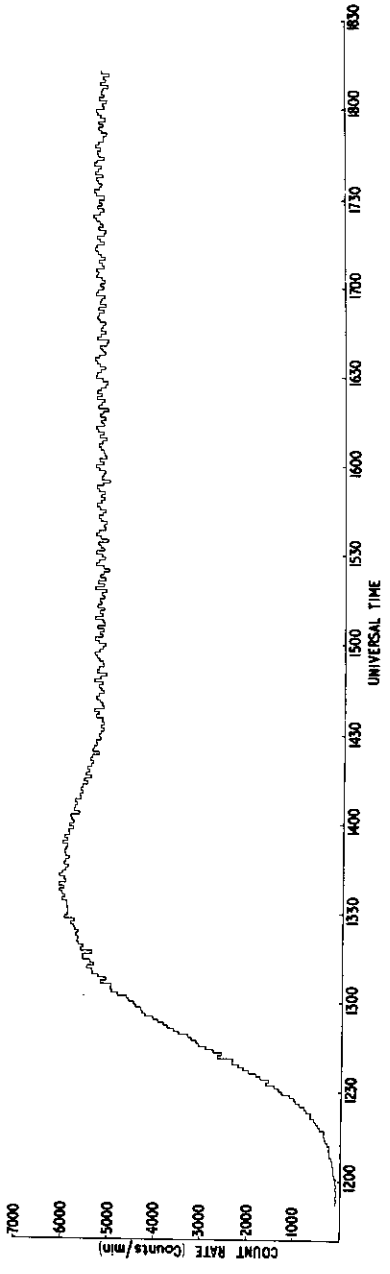

FIG. 18. Geiger (shielded) count rate, Flight 2, 7 March 1964.

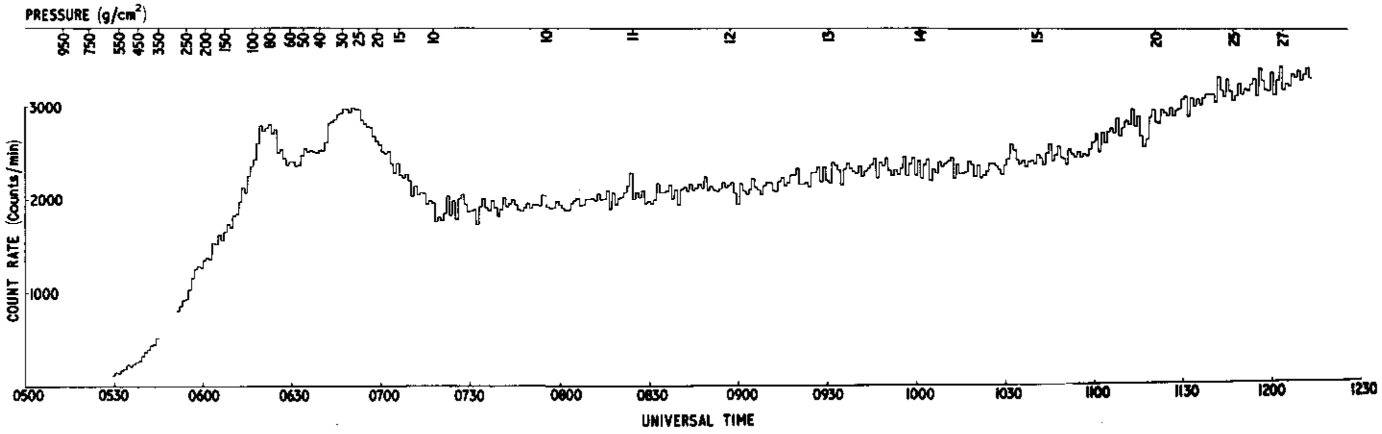

FIG. 19. Neutron count rate, Flight 3, 18 March 1964.

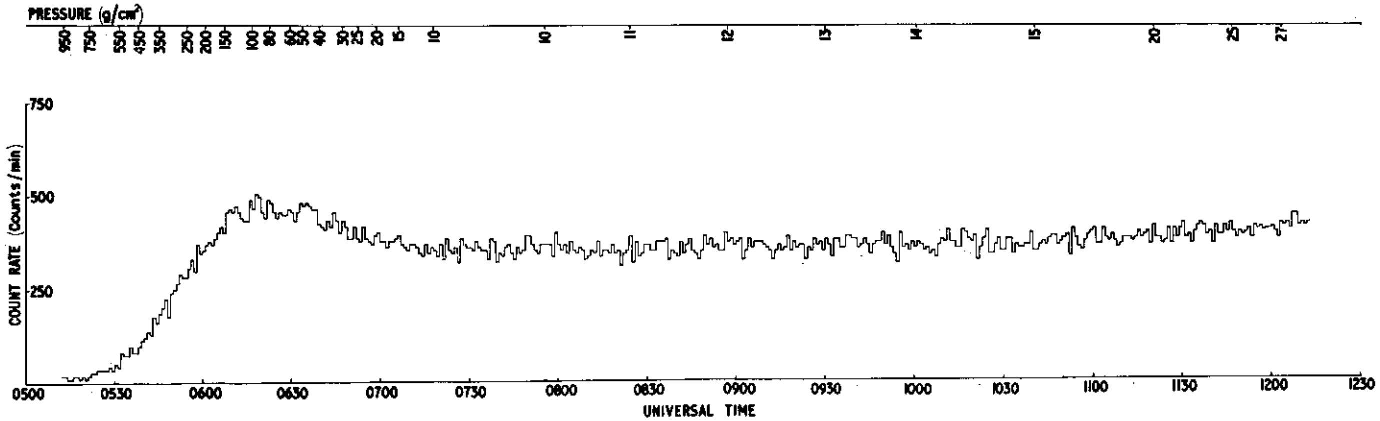

FIG. 20. Triple coincidence count rate, Flight 3, 18 March 1964.

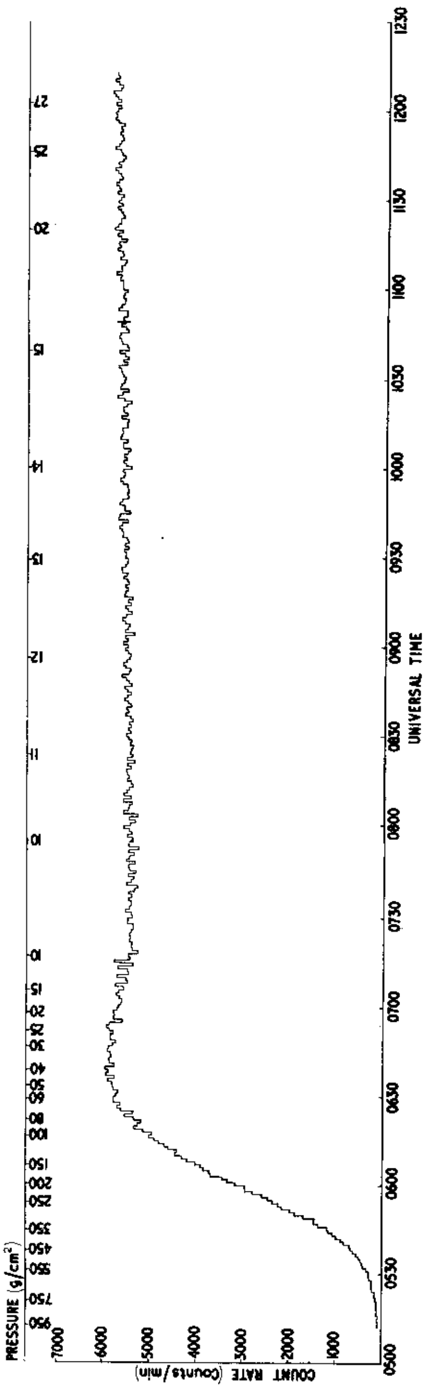

FIG. 21. Geiger (unshielded) count rate, Flight 3, 18 March 1964.

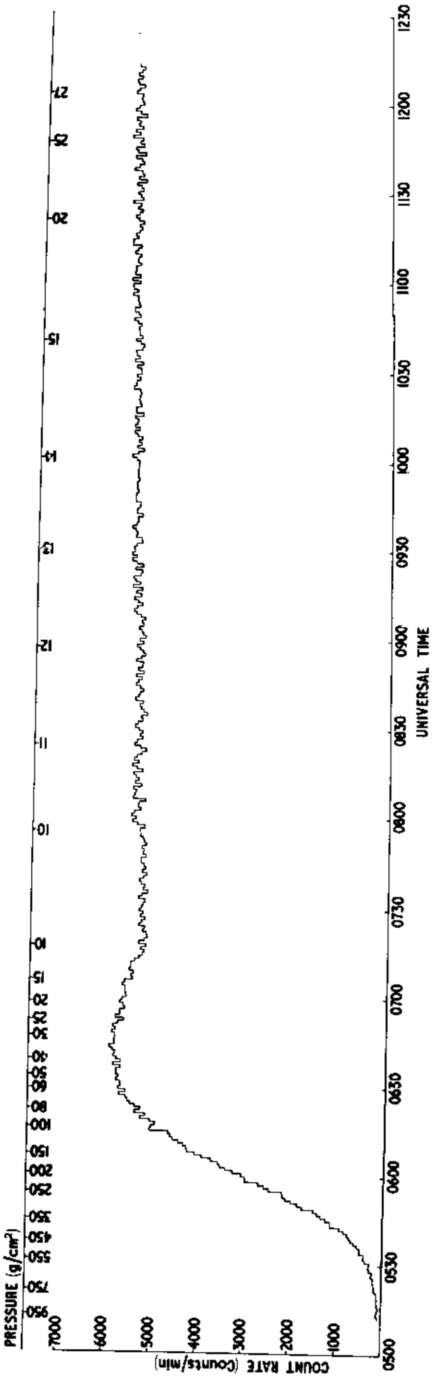

FIG. 22. Geiger (shielded) count rate, Flight 3, 18 March 1964.

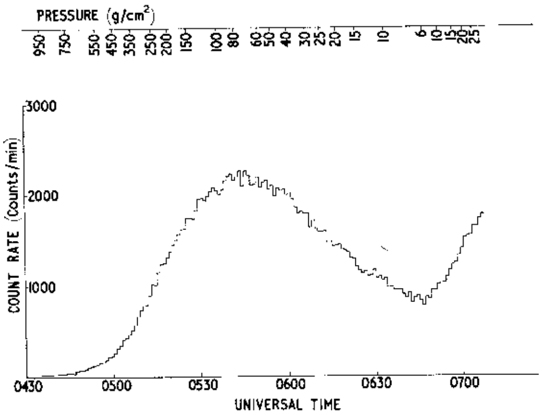

FIG. 23. Neutron count rate, Flight 4, 20 September 1964.

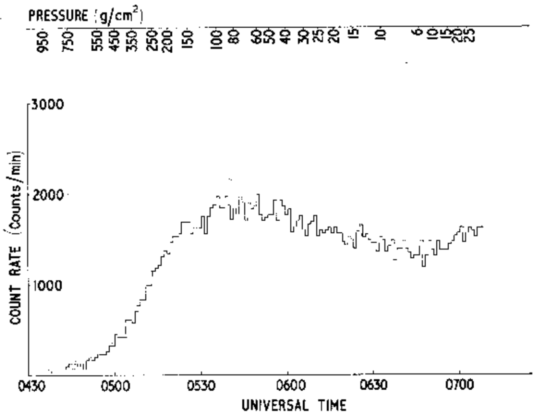

FIG. 24. Triple coincidence count rate, Flight 4, 20 September 1964.

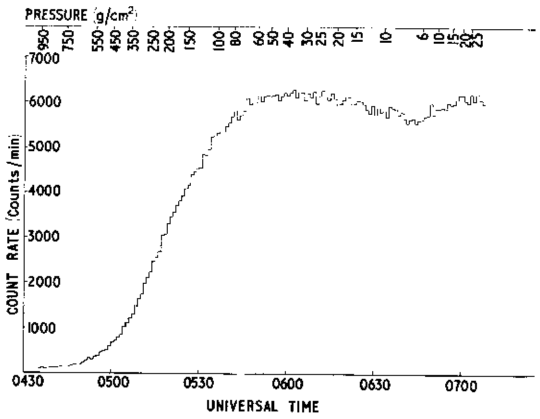

FIG. 25. Geiger (unshielded) count rate, Flight 4, 20 September 1964.

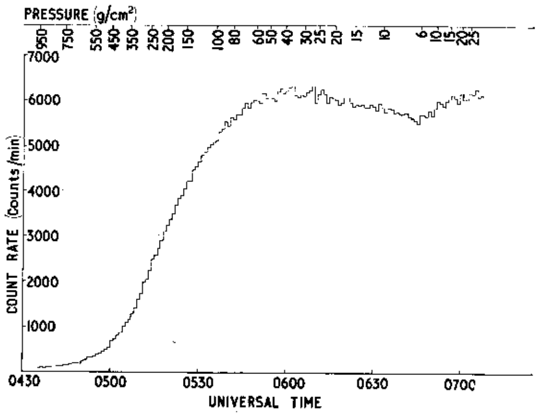

FIG. 26. Geiger (shielded) count rate, Flight 4, 20 September 1964.

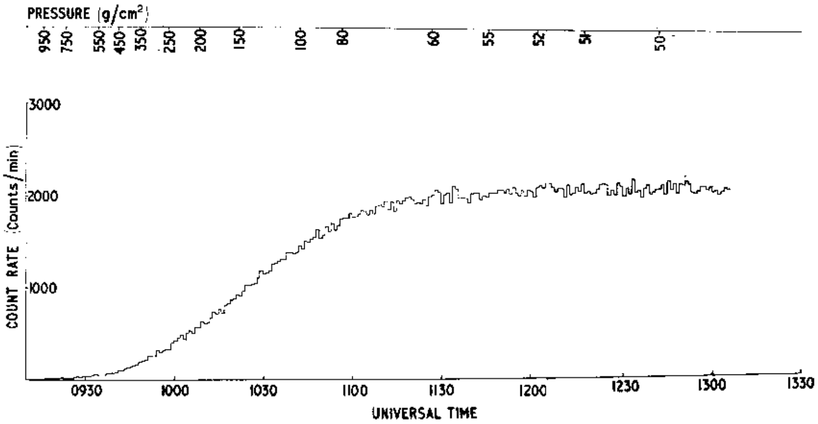

FIG. 27. Neutron count rate, Flight 5, 27 September 1964.

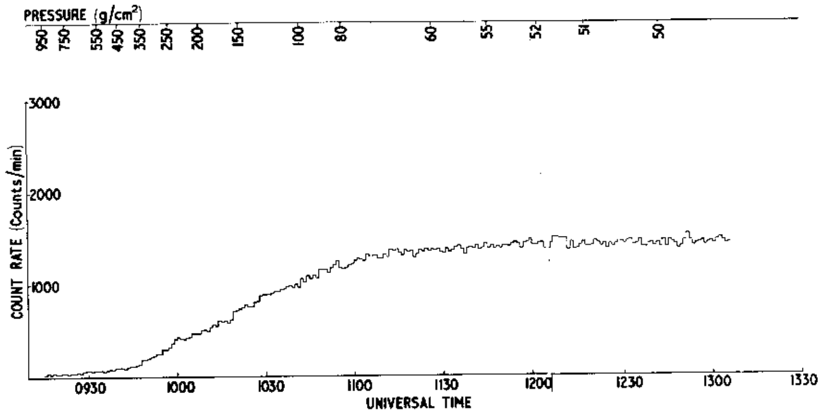

FIG. 28. Double coincidence count rate, Flight 5, 27 September 1964.

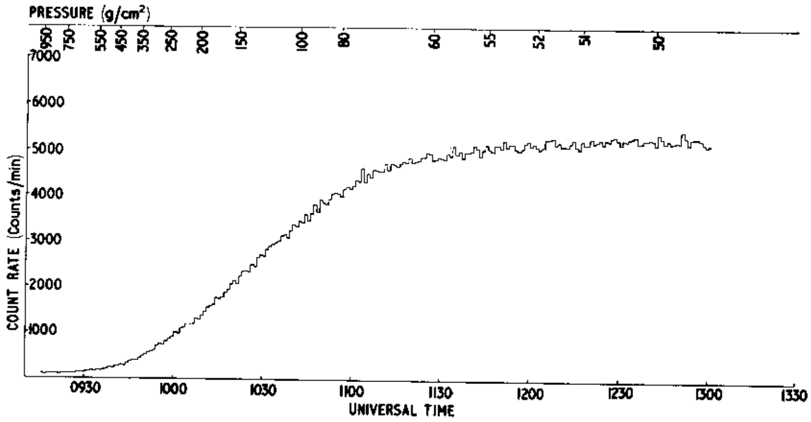

FIG. 29. Geiger (unshielded) count rate, Flight 5, 27 September 1964.

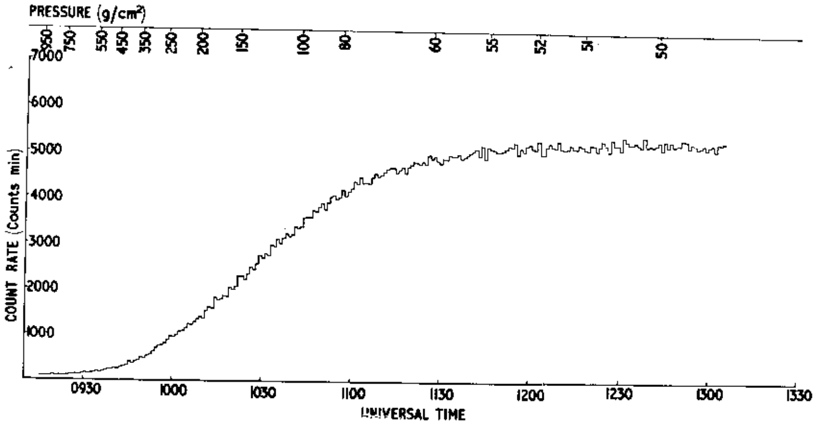

FIG. 30. Geiger (shielded) count rate, Flight 5, 27 September 1964.

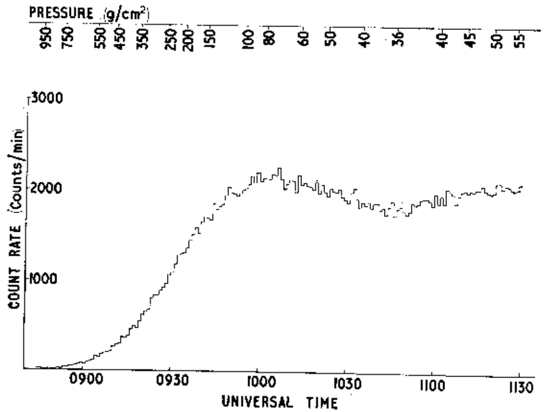

FIG. 31. Neutron count rate, Flight 6, 2 October 1964.

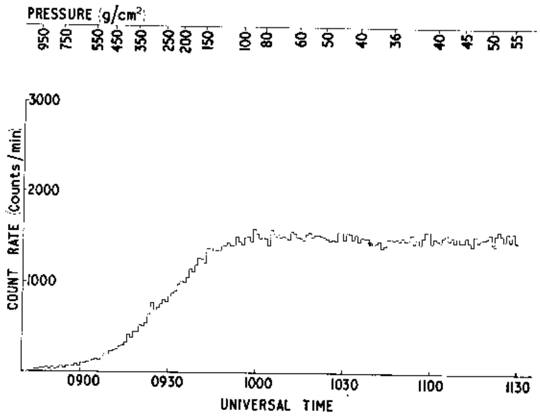

FIG. 32. Double coincidence count rate, Flight 6, 2 October 1964.

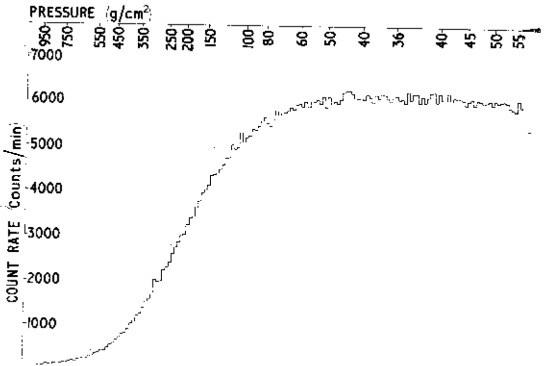

FIG. 33. Geiger (shielded) count rate, Flight 6, 2 October 1964.

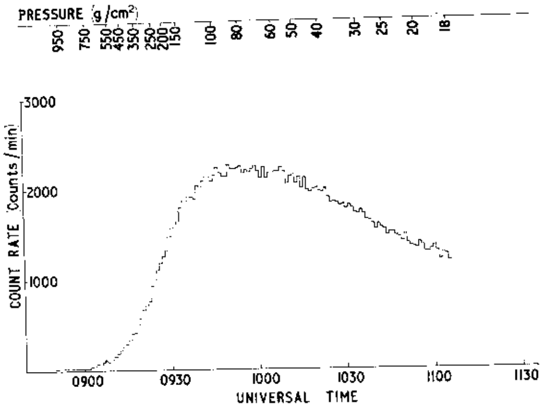

FIG. 34. Neutron count rate, Flight 7, 7 October 1964.

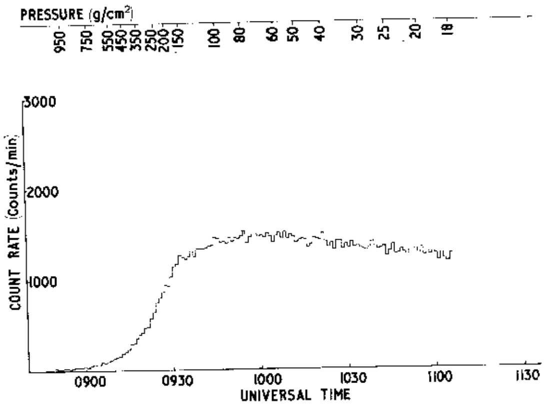

FIG. 35. Double coincidence count rate, Flight 7, 7 October 1964.

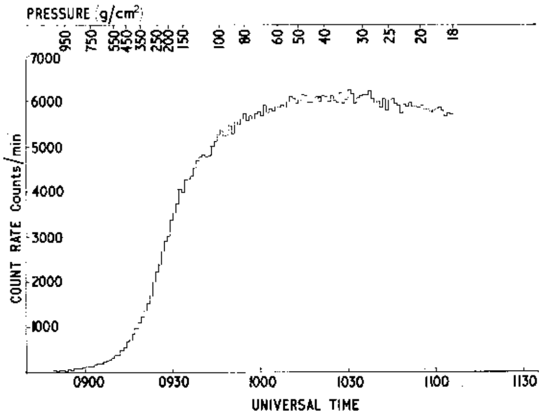

FIG. 36. Geiger (unshielded) count rate, Flight 7, 7 October 1964.

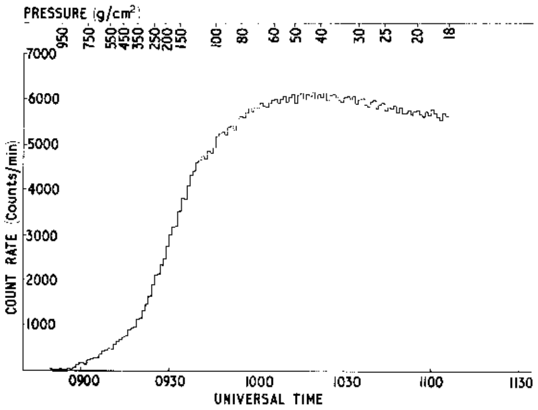

FIG. 37. Geiger (shielded) count rate, Flight 7, 7 October 1964.

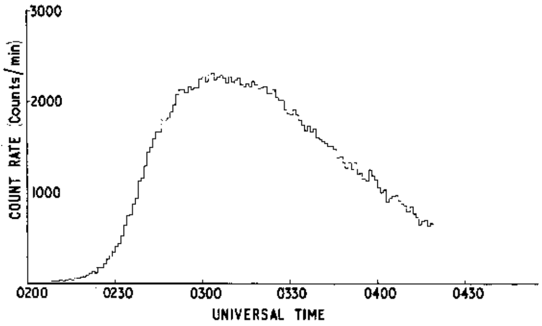

FIG. 38. Neutron count rate, Flight 8, 17 October 1964.

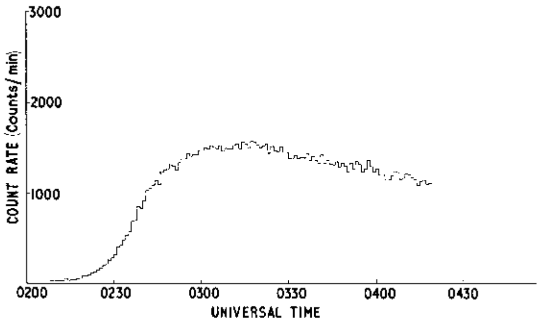

FIG. 39. Double coincidence count rate, Flight 8, 17 October 1964.

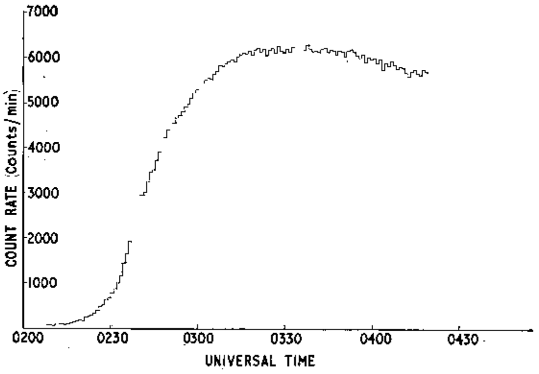

FIG. 40. Geiger (unshielded) count rate, Flight 8, 17 October 1964.

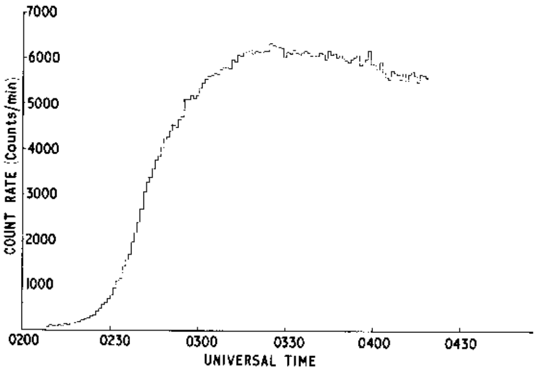

FIG. 41. Geiger (shielded) count rate, Flight 8, 17 October 1964.

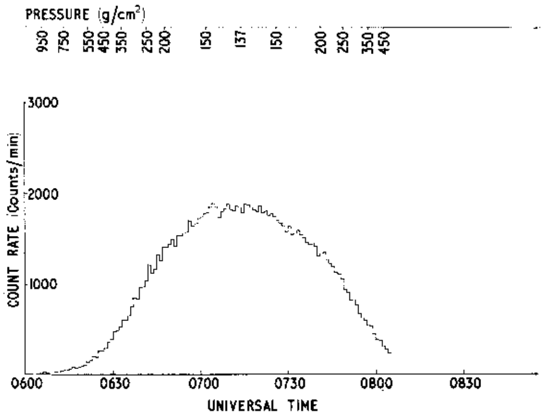

FIG. 42. Neutron count rate, Flight 9, 21 October 1964.

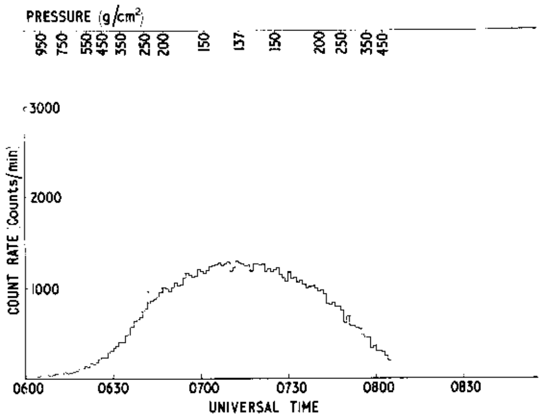

FIG. 43. Double coincidence count rate, Flight 9, 21 October 1964.

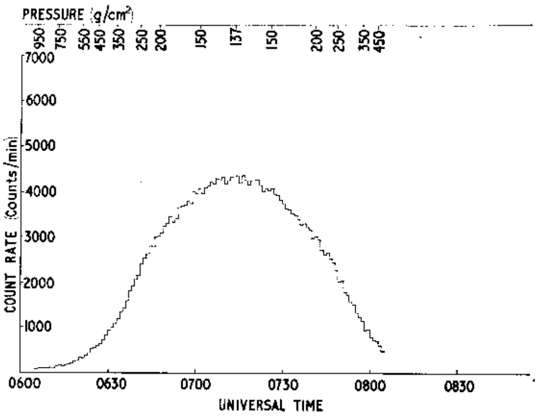

FIG. 44. Geiger (unshielded) count rate, Flight 9, 21 October 1964.

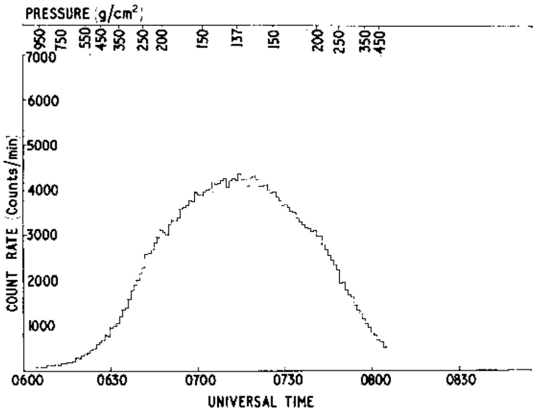

FIG. 45. Geiger (shielded) count rate, Flight 9, 21 October 1964.

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