Observation of Cosmic-Ray Neutron Intensity at Morioka*

Part I. The Neutron Monitor

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(Received May 15, 1971)

Abstract

A Simpson's type neutron monitor consisting of six $^{10}$F$_3$ counters was set up in the campus of Iwate University in May 1970. This paper gives the details of the monitor, together with some observation results obtained by it. The monitor is being operated in good condition since August 1970 after preliminary operation for about three months.

I. Introduction

Continuous observations of cosmic-ray neutron intensity were preliminarily carried out by the pioneers; Simpson1), Elliot2) and other authors3). Preliminary measurements of the cosmic-ray neutron intensity in Japan were begun on Mt. Norikura (geomagnetic latitude 25.7°N, height 2770 m) in 1955, using four normal $^{10}$F$_3$ counters4). At the meeting of SCRIV*** on the standardization of the cosmic-ray neutron monitor, general specifications of the apparatus for the neutron intensity measurement were decided and Simpson's type1) was recommended to be used as its standard neutron monitor. During the International Geophysical Year (July 1957 – December 1958) continuous observations of the cosmic-ray neutron intensity, using the standard Simpson's type neutron monitor, have been carried out under the world-wide network of cosmic-ray stations inclusive of the Japanese station, Mt. Norikura. Since then until now many of them have been carrying out such an observation.

In May 1970 we installed such a Simpson's type neutron monitor in the campus of Iwate University at Morioka (the details of its location are given in Table 2) in order to observe continuously the neutron intensity of cosmic rays.

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The monitor has been operated in good condition since August 1970 after preliminary operation during about three months.

![Block diagram of the monitor.](image)

The block diagram of the monitor is shown in Fig. 1. The details of the monitor and some observation results by the monitor will be given in the following. Coefficient for barometric effect will be given and discussed in Part II\(^{10}\) by Chiba, one of the authors.

II. \(\text{B}^{10}\text{F}_3\) Proportional Counters and the Neutron Pile

The \(\text{B}^{10}\text{F}_3\) proportional counters used in the monitor have the same structure as illustrated in the reference\(^9\). The neutron detector consists of six \(\text{B}^{10}\text{F}_3\)

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Plate 1. Structure of neutron pile.
C; counter, Pb; lead, P; paraffin,
W; copper net, MB; metal box.
counters of such a structure, located in a paraffin and lead pile of Simpson's type as shown in Plate 1.

Fig. 2. Counting rates as a function of voltage.
(a); for respective counter.
(b); for a mixture of respective counters.
For checking the counters, their counting rates as a function of voltage were examined, using a radioactive source, for both respective counter and total (six) counters connected with each other, arranged in the lead-paraffin pile as shown in the plate. The results are given in Fig. 2-(a) and -(b) and also in Table 1. As seen from the figure and the table, the plateau range for respective counter is within 2.70-3.15 kV. The plateau slope is 0.44 percent per 100 volts on average and is nearly zero for a mixture of respective counters, being sufficiently small. It follows from these data that the counters act normally and the working voltage should be set in 2.95 kV.

For observing stably the neutron intensity, the monitor should be left free from any electric disturbances from outside. Thus the lead bricks of the pile were surrounded by both a copper net and two metal boxes, shown by the symbols ‘W’ and ‘MB’ in the plate, for the purpose of shielding.

### Table 1. Characteristics of neutron counter

<table>
<thead>
<tr>
<th>Counter</th>
<th>Plateau</th>
<th>Slope (&lt;%/100V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>2.75-3.10</td>
<td>0.85</td>
</tr>
<tr>
<td>No. 2</td>
<td>2.75-3.10</td>
<td>0.50</td>
</tr>
<tr>
<td>No. 3</td>
<td>2.80-3.10</td>
<td>0.63</td>
</tr>
<tr>
<td>No. 4</td>
<td>2.80-3.15</td>
<td>0.26</td>
</tr>
<tr>
<td>No. 5</td>
<td>2.70-3.15</td>
<td>0.22</td>
</tr>
<tr>
<td>No. 6</td>
<td>2.75-3.15</td>
<td>0.17</td>
</tr>
<tr>
<td>Total</td>
<td>2.85-3.05</td>
<td>~0</td>
</tr>
</tbody>
</table>

* Six counters (No.1, No.2, ....... and No.6) are connected with each other in the lead-paraffin pile.

III. Electronic Circuits, Recorder and Barometer

To record the cosmic-ray neutron intensity a set of neutron counters was connected with electronic circuits and recorder, as shown in Plate 2. The outlines of the main electronic circuits and the recorder (digital printer) are as follows.

1. Pulse amplifier (Kōbe Kōgyō PA-11)
   - Gain: 295, Resolving power of time: 0.5 \( \mu \)s, Input impedance: 25 kΩ, Output impedance: 23 Ω.

2. Scaler (Kōbe Kōgyō SA-203)
   - This unit consists of linear amplifier, discriminator, scaler, low voltage supply and high voltage supply. Input sensitivity: negative pulse of more than 10 mV. Maximum counting: \( 2^7 \) (=128) based on the binary system, Resolving power: less than 3 \( \mu \)s, High voltage: 2500~3500 V, variable.
Plate 2. A view of electronic instruments, recorder connected with neutron counters, and barometer.
NP; neutron pile, PA; pulse amplifier, S; scaler, Pr; printer, T; timer, B; barometer.

(3) Printer (SODECO PL 103)
Maximum pulse frequency: 10 counts/s,
Minimum pulse duration: 50 ms,
Minimum interval duration: 50 ms.
Pulses from the scaler are fed into the printer, in which counting rates are printed on a sheet once every fifteen minutes, following a signal from the timer, as shown in Plate 3.

In addition, an automatic pen-recording barometer is operated separately, as seen in Plate 2, in order to obtain barometric pressure data for preliminary correction of the observed neutron intensity for barometric effect.

IV. Observation results and Discussion

The monitor has been installed in the prefabricated hut, shown in Plate 4, near Physics Department in the campus of Iwate University. Its location is given in Table 2, together with that of the Morioka Local Meteorological Observatory, from which final barometric pressure data are supplied for correction of the counting rates. As is known from the table, the height difference between the two stations is 21.4 m, which is equivalent to about 2.6 mb of the barometric pressure.
Plate 3. A view of digital printer.

Table 2. Location of observational station

<table>
<thead>
<tr>
<th>Station</th>
<th>Geographic</th>
<th>Height</th>
<th>Cut-off rigidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Longitude</td>
<td>Latitude</td>
<td></td>
</tr>
<tr>
<td>Iwate University</td>
<td>141°08′E</td>
<td>39°42′N</td>
<td>135.0 m</td>
</tr>
<tr>
<td>Morioka Local</td>
<td>141°10′E</td>
<td>39°42′N</td>
<td>156.4 m</td>
</tr>
<tr>
<td>Meteorological Observatory</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order to keep the monitor always in good condition and to obtain reliable data, inside the hut it is devised to be kept within a suitable temperature range of 10–30 °C throughout a full year. Moreover, a special device was made for the hut so as to be free from snow effect in winter season.

Prior to observation at Morioka the present monitor had been operated at Cosmic Ray Laboratory, the Institute of Physical and Chemical Research, Itabashi, Tokyo (geomagnetic latitude 25.5°N, height 20 m) in the same construction as that at Morioka, in order to check the counting rates obtained at Morioka in comparison with those at Itabashi. Table 3 shows the counting rates at both stations, together with the periods of operation and the correlation coefficients between the counting rate and the barometric pressure. All of the counting rates are reduced to the value at barometric pressure 1,000 mb. Figs. 3 and 4 give examples of correlation between the counting rate and the barometric pressure.

Suda and Kodama have obtained the ratio of the counting rate at Morioka to that at Itabashi, using the similar neutron monitor to ours, the value of which gives +12.2 %. Such a ratio obtained from the weighted means given in Table 3 is +13.5 ± 5.3 % in case of using the weighted mean of the counting rates observed in the wooden hut at Itabashi and +57.8 ± 1.7 % in case of using that in the ferroconcrete building at Itabashi. The former, +13.5 ± 5.3 %, is plausible in comparison with the value +12.2 % given above. On the one hand, the latter is greatly different from the expected value. This is supposed to be
Table 3. Counting rate and its correlation coefficient with barometric pressure

<table>
<thead>
<tr>
<th>station</th>
<th>Period</th>
<th>Number of days</th>
<th>Counting rate $\times 8$ (hr$^{-1}$)</th>
<th>$r$***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morioka</td>
<td>August 1970</td>
<td>21</td>
<td>1190.3</td>
<td>-0.981</td>
</tr>
<tr>
<td></td>
<td>September 1970</td>
<td>30</td>
<td>1198.3</td>
<td>-0.986</td>
</tr>
<tr>
<td></td>
<td>October 1970</td>
<td>31</td>
<td>1195.0</td>
<td>-0.982</td>
</tr>
<tr>
<td></td>
<td>November 1970</td>
<td>30</td>
<td>1189.5</td>
<td>-0.940</td>
</tr>
<tr>
<td></td>
<td>December 1970</td>
<td>31</td>
<td>1212.0</td>
<td>-0.995*</td>
</tr>
<tr>
<td>Weighted mean</td>
<td></td>
<td></td>
<td>1197.0±9.1*</td>
<td>0.977</td>
</tr>
<tr>
<td>Itabashi*</td>
<td>March 1970</td>
<td>31</td>
<td>764.0</td>
<td>-0.981*</td>
</tr>
<tr>
<td></td>
<td>April 1970</td>
<td>30</td>
<td>753.3</td>
<td>-0.958</td>
</tr>
<tr>
<td>Weighted mean</td>
<td></td>
<td></td>
<td>758.7±7.6*</td>
<td>0.970</td>
</tr>
<tr>
<td>Itabashi**</td>
<td>Dec.1966~Nov.1967</td>
<td>99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted mean</td>
<td></td>
<td></td>
<td>1055±54*</td>
<td>0.995</td>
</tr>
</tbody>
</table>

* The monitor was set in a ferroconcrete building.
** The monitor was set in a wooden hut*.
*** Coefficient of a simple correlation between counting rate and barometric pressure.
$^* $ Standard error.
Correlations (1) and (3) are shown graphically in Figs. 3 and 4. Barometric pressure data used to evaluate $r$ at Morioka are supplied from the Morioka Local Meteorological Observatory.

![Graph 1](image1)

![Graph 2](image2)

Fig. 3. Correlation between counting rate and barometric pressure.
(a) and (b) give the correlations (1) and (3) shown in Table 3, respectively.
due to the circumstance that in this case at Itabashi the monitor was set in the ferroconcrete building having the roof of a considerable thickness.

From the above, it is concluded that the counting rates of the monitor at Morioka are reasonable and the monitor itself has been operated stably and reliably.

**Acknowledgments**

This neutron monitor was kindly supplied from Cosmic Ray Laboratory, the Institute of Physical and Chemical Research, by a courtesy of Dr. M. Kodama, a member of the Laboratory. We are also very much indebted to him for valuable advices and helpful discussions. Our thanks are also due to the members of Iwate University for their kind assistance, particularly for construction of the observation hut. Supplies of the barometric pressure data owe to the Morioka Local Meteorological Observatory. Most of the calculations were carried out by use of the computer FACOM 231 of Iwate University.

This work was partially supported by the Scientific Research Fund of the Ministry of Education.
References

2) H. Elliot: Bagneres Meeting (1953).