DATA PROCESSING SYSTEM AND RELIABILITY TESTS THE LOMNICKY STIT 4-NM-64 MONITOR DATA*

ANDREJ FUTÓ**, JURAJ DUBINSKÝ**, Košice

The paper describes the data collecting hardware of the neutron monitor 4-NM-64 at Lomnický štít together with the software system developed for the evaluation and reliability tests of the recorded data. The aim of the work is to develop for the given instruments and given laboratory work organization and optimal data processing system in which every measured value is tested several times before being included or eliminated from the measured time series. The data processing system results are two sets of data available for the world cosmic ray laboratories network and world data centres.

I. INTRODUCTION

Between 1970 and 1972 a neutron monitor 4-NM-64 was constructed at the Institute of Experimentsl Physics of the Slovac Academy of Sciences at the Lomnický štít laboratory. The aim in constructing the new instrument was to increase the recorded counting rates from the range value of 10^5 pulses/hour with the old instrument — a Simpson monitor [3]—, to the range value of 10^6 pulses/hour with NM-64. Thus the measurement statistical error is diminished and this enables the study of more subtle cosmic ray variations. Together with the construction of the instrument the project of a data prosessing system became necessary.

The cosmic ray intensity registrations represent a long time measurement. To achieve the aim of the experiment it is necessary to register at least during one solar cycle (11 years). It is desirable to secure the functional stability of the instrument during this long period, to develop the electronic stability testing of the individual apparatuses and to propose the statistical testing of reliability of the registered data. At the same time it is necessary to remember the various ways of the bad functioning or breakdown of the individual

* The present paper is a part of references [1].

** Ústav experimentálnej fyziky SAV, 040 01 KOŠICE, Moyzesova 11 .

apparatuses and to propose corrections for experimental errors originating in that way.

Except for general principles there is no internationally accepted method of a data processing system; there exists only an agreement concerning the monthly intensity tables which are being exchanged among the laboratories and which are published after several years in the world data centres. A rapid exchange of the measured data and their normalization to one and the same instrumental registration level are naturally most desirable.

The presented data processing system is aimed at discovering in the counting rate changes those not caused by changes in the cosmic ray intensity. We keep strictly to the principle not to eliminate the recorded effect unless we can state with the maximum probability that the recorded effect has been caused by a failure of the recording device.

The data processing is divided into four stages: the daily, fortnightly, quarterly and final treatment.

II. REGISTRATION EQUIPMENT DESCRIPTION

The 4-NM-64 registration equipment, Fig. 1, consists of a central unit, a digital barometer, a time circuit, an hourly data paper tape puncher, a five minute data paper tape puncher and a pen recorder. The pulses from the NM-64 counter are fed into registers in the contral unit. Every 5 minutes there comes an impulse from the time circuit which reads into the buffer the instantaneous value of the difference between the counting rate in the registers and the previous counting rate in the buffer. The infornation from the buffer is then punched in the CCITT code on the paper tape together with the registration time information. A 5-minute record contains on the whole: the

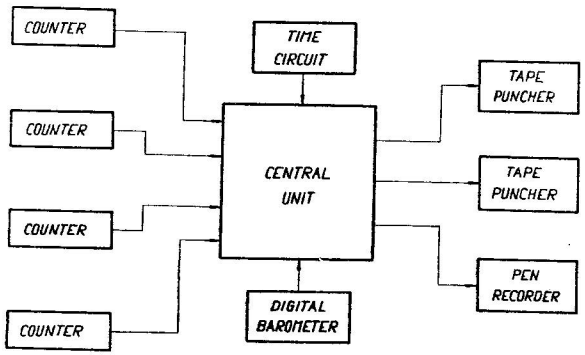

Fig. 1. Hardware system flowchart

year, the sequence day number in the year, the hour, the minute, the pressure, the intensity in the channels A, B,C,D. After 12 5-minute records the registers are automatically set to zero. Before their setting to zero the contents of the registers — which now represent the one-hour record — are read out. The one-hour record contains information of the same structure as the 5-minute one. The 5-minute record is read out in the same way as in the previous case, but after its reading out the content of the buffer is set to zero, too.

In order to continue the cosmic ray intensity registration ever after the breakdown of both punchers, there exists an auxiliary pen recorder for the intensity registration of all four NM-64 channels.

The central unit is fed from accumulator sources as a protection against tension peaks of the feeding net and because of relatively frequent voltage failures.

The proportional functioning of counters is checked by a 512 channel pulse height analyzer.

III. APPLIED STATISTICAL METHOD [4]

The 4-NM-64 is divided into four mutually independent sections. The sections are situated identically with regard to both the measured radiations and the meteorological conditions. Thus the recorded counting rates differ only by a different efficiency of the electronic units and by random statistical fluctuations. The ratios between sections when these are working properly are constant except for the statistical noise.

Deviations from a constant ratio or larger fluctuations may be due to any factor that alters the total counting rate of one section only. For instance [2]:

1. The damaging of a counter.
2. The replacing of a counter.
3. A change in the counter position relative to the producer.
4. Breakdown pulses in the counter.
5. Changes in the voltage applied to the counter.
6. A shift of the discriminator level.
7. A change in the amplifier dead-time (pulse-width).

Factors which affect every section can only be revealed by comparing the counting rates of every section with the counting rate recorded in other stations with similar geomagnetic conditions. For instance [2]:

1. Simultaneous changes in electronic parameters (discriminator levels, amplifier dead-time) due to changes in the laboratory temperature, the ageing of the equipment, etc.
2. Change in the test equipment calibration.
3. Demolition or erection of adjacent buildings, etc.

4. Changes in the absorbing material around the monitor (including snow on the roof, snowdrifts, etc.).
5. Variations in the environmental neutron background.
6. Incomplete correction for meteorological effects.

Let us study the following properties in the counting rate ratio time sequence:
1. Plotting versus time for visual checking — the time course of two channel ratios of two properly working sections will show only statistical fluctuations around a constant mean.
2. Distribution of the ratios — they will form an approximately Cauchyan, thus symmetrical, distribution.
3. Autocorrelation coefficients — their values will be close to zero as only the statistical noise is present when the sections are working normally.

The above mentioned test series gives no information about errors which affect every section simultaneously. Forming ratios of the counting rates of individual channels after barometric pressure correction and the counting rate of one or several other cosmic ray intensity registration stations situate in similar geomagnetic conditions, we obtain a suitable complement to the internal tests and we can analyze such ratios according to the above mentioned points 1—3.

IV. COSMIC RAY INTENSITY AND BAROMETRIC PRESSURE DATA PROCESSING

The data processing is divided into four stages: daily, fortnightly, quarterly and final data processings. The daily data treatment is done manually directly at Lomnický štít. The following stages are processed on the computer. The computer processing scheme is in Fig. 2. The *PRETEST* and *PREDIST* programs belong to the fortnight-processing, the *SNAKES*, *PCOF*, *DISTNM*, *DISTPR* and *RATIOS* programs to the quarterly processing and the program

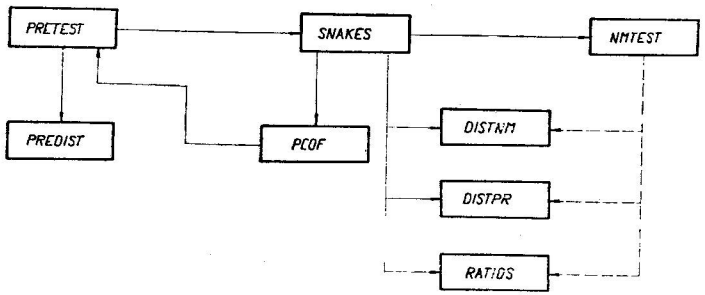

Fig. 2. Flowchart for the data treatment

NMTEST or the programs *DISTNM*, *DISTPR* and *RATIOS* to the final processing, respectively. For the *PRETEST*, *SNAKES* and *NMTEST* programs sets of various additional programs could be written ad hoc for correction, rearrangement and smoothing of data. *FORTRAN* program texts, their descriptions and examples of their publications are available at the Institute.

In the following we shall discuss the individual stages of data processing.

V. DAILY DATA TREATMENT

The daily data treatment begins at Lomnický štít and consists of two parts:
1. The one-hour data treatment, which consists of the following phases:
a) Check of the formal layout of the one-hour record by means of the teletype ZBROJOVKA or its correction in case of error. The correctness of the data, time and approximately of the pressure value and the numerical value of the intensity in the individual channels are checked.
b) By means of the calculator ELKA the counting rate ratios of the channels A/B, C/B, A/D, C/D are calculated.
c) The calculated ratios are drawn on mm-paper to obtain the first information about the measurement stability.
d) When there is in any channel at any hour an intensity value which is incorrect at first sight, it is necessary to apply the 5-minute data and to obtain the actual one-hour data by adding the appropriate 5-minute data. If it is impossible, one must use the pen records and obtain through them the one-hour data. If it is impossible, the one-hour data are set to zero.
e) The numerical values of the barometric pressure are checked with the help of records of the Department of the Hydrometeorological Institute at Lomnický štít.
f) The checked and corrected one-hour data are drawn on mm-paper together with the barometric pressure so that we may obtain a picture of their course.
2. The 5-minute data treatment which consists of the following phases:
a) Check of the formal record layout as in point 1a.
b) If, according to point 1f, there is a longer increase or decrease of intensity which has not been caused by a sudden pressure change, by some other defect of the instrument or by a laboratory temperature change, the course of the 5-minute intensity in the channels A, B, C, D, their sum $A + B + C + D$ and pressure values are drawn on mm-paper. In this way some phenomena as, e.g., the Forbush decreases or the solar flare effects are observed [5].
c) The 5-minute records are no longer treated. The criteria for judging the 5-minute data are the following: Every intensity value with a magnitude within $\pm$ 25 % (pressure $\pm$ 0.7 mm Hg) of the preceeding value is acceptable.

Values not obeying these rules are set to zero. The mentioned criteria result from the cosmic ray intensity variations observed so far.

The service at Lomnický štít takes fortnightly turns. Those of the personnel who are of duty send the punched paper tapes of the one-hour and 5-minute data together with the equipment functioning protocols and the mm-papers recording the intensity and ratio courses to the Institute in Košice for further processing.

VI. FORTNIGHTLY DATA TREATMENT

The fundamental program of the fortnightly data treatment is the test program *PRETEST* and a program for the preliminary distribution of the cosmic ray intensity tables *PREDIST*.

The data treatment begins with the *PRETEST* program. First the uncorrected hourly intensity values together with the computed daily average and fortnightly means of the individual channels are tabulated. The hourly pressure value and daily and fortnightly pressure value averages are tabulated similarly. Then the zero pressure values are searched — for these the intensity is not corrected, othervise the intensity is corrected to barometric pressure. After the correction the cards for the corrected intensity of the individual channels of the NM-64 are punched. The course of the corrected intensity is plotted; the intensities in the individual channels are summed up and punched on cards. The corrected intensity values in the individual channels as well as their sums are tabulated similarly as the uncorrected intensity. Then the hourly intensity ratios are produced, the same as in the daily treatment and are tabulated, plotted and histogramized in the above way. Finally the variances and autocorrelation coefficients are computed and printed from the mentioned ratio classes with a time lag of 1—5 hours.

After the *PRETEST* program the manual check of the zero intensity values and those intensity values which differ by more than $\pm 3\sigma$ from the fortnightly intensity mean follow. The following corrections are possible:

1. One single hour value is missing or wrong — the value is interpolated.

2. One channel changes its efficiency but is working well before and after the change — the ratios between the counting rates before and after the change are calculated and the efficiency is restored to the former level.

3. Data from a single channel are missing or wrong for more than one hour — the ratio between the faulty channel and the two correct channels is calculated for a period of 5 hours before and 5 hours after the defect. This ratio is used to fill the gap of the faulty channel. This method can also be used to correct or to complement the data of two faulty channels.

4. Three or all channels are empty or out of repair for more than one hour — the corresponding data are taken from the 5-minute records or the pen recorder registration. If it is not possible, the counting rate for this hour is put equal to zero.

If in the manual test extensive corrections are made, it is desirable to test the fortnightly interval again with the test program *PRETEST*.

After the manual test the sums of the values of the NM-64 four channels are tabulated and plotted by the *PREDIST* program. These preliminary tables are distributed to other laboratories with which we have an agreement about the preliminary data exchange.

VII. QUARTERLY DATA TREATMENT

The quarterly data treatment is based on the following programs:

SNAKES — a test program

PCOF — a program for the barometric coefficient evaluation [7]

DISTNM — a program for the distribution of the monthly tables of the cosmic ray intensity corrected to barometric pressure

DISTPR — a program for the monthly barometric pressure tables distribution

RATIOS — a program for the NM-64 four channel daily intensity ratio distribution

The quarterly data treatment begins with the SNAKES program. It reads the hourly data of a three months' interval from four NM-64 channels corrected to barometric pressure and hourly intensity values corrected to the barometric pressure of the comparating station. The daily intensity means are computed — in the case of more than four hourly values being zeros on the particular day, the daily mean is set to zero. Then the four channel sum of our NM-64 is evaluated and this sum is punched. The computing of the hourly intensity ratios of the channels A/B, C/B, A/D, C/D follows and these ratios are histogramized. The ratios of the daily intensity means in channels A/B, C/B, A/D, C/D the,. daily means of the sum $A + B + C + D$/comparing station, the ratios of the daily intensity means in the individual channels A, B, C, D/comparating station are computed and together with the daily intensity means in the individual channels and the comparating station are tabulated. Then the autocorrelation coefficients with a time lag of 1—5 hour are computed for the above mentioned daily intensity mean ratio classes. Finally the following are plotted:

1. The daily intensity mean courses in the individual channels, their sums and the values of the comparating station.
2. The daily intensity mean ratio courses A/B, C/B, A/D, C/D.

3. The daily intensity mean courses in the channels A, B, C, D, $A + B + C + D$ and the comparating station.

The transition from the hourly intensity ratios to the daily mean intensity ratios permits to observe small changes lasting a long time in the individual channel functions.

After the *SNAKES* program there follows the manual test of zero intensity values according to the principles mentioned in the fortnightly data treatment When a shift lasting a long time is discovered in the counting rate, the correction factor for multiplying data from the faulty time interval is computed. Provided that the corrections are extensive it is desirable to test the tested quarterly interval again with the test program *SNAKES*.

After the manual test the computation of the barometric coefficient with the help of the data in the summed channels $A + B + C + D$, the barometric pressure and the corrected hourly data of the comparating station are carried out with the help of the *PCOF* program.

After the manual test there follows independently of the *PCOF* program, the tabulation of the hourly intensity values in the summed channels $A + B + C + D$ or the barometric pressure values, respectively, in the form of mothly tables with the help of the *DISTNM* or the *DISTPR* program and of the quarterly tables of the daily mean intensity ratios of the sections A/B, C/B, A/D, C/D with the help of the *RATIOS* program. These tables are distributed to other laboratories and to the world data centres.

VIII. FINAL DATA TREATMENT

The final data treatment is carried out with the data from a time interval of 3—12 months. It is based on the *NMTEST* test program. It reads the data corrected to the barometric pressure from two to five different stations with an approximately equal cut-off rigidity from the mentioned time interval. The mean counting rate for each station is computed, which serves for the normalization of data for the given station. Then the evaluation of the mean intensities of every NM-64 represented by their sum follows. The daily mean intensity ratios of the individual NM-64 versus the mean intensity, the autocorrelation coefficients with a time lag of 1—5 days for the considered intensity ratio classes are printed, histogramized and plotted.

The long time function stability of our NM-64 is judged from the *NMTEST* program output. When a shift lasting a long time is discovered in the counting rate, the correction factor for multiplying the data of the faulty time interval is computed. After extensive corrections it is desirable to test the tested interval again with the *NMTEST* test program, new data are tabulated by the

DISTNM and the *RATIOS* program and similarly as in the quarterly data treatment are distributed to other laboratories. In the case of non-extensive corrections only the correction factor for the faulty time interval is announced.

IX. DISTRIBUTION OF DATA

The aim of the presented data processing system is a distribution of properly measured data which are stable for a long time and normalized to the same efficiency of registration. For this end two sets of data are prepared:

1. The preliminary fortnightly data. The printlist and a rough graph of the cosmic ray intensity corrected to the barometric pressure are presented. These data are available on other input media, too (e.g. punched cards, magnetic tapes) directly suitable for a computer, for the laboratories which exchange data with us in the same manner. These data lists are distributed one week after obtaining the measured data from Lomnický štít.

2. The monthly tables of the cosmic ray intensity corrected to the barometric pressure, the monthly tables or barometric pressure registration and the quarterly tables of daily mean intensity ratios in the four channels of NM-64.

This data presentation should be regarded as definitive. Any corrections made as a result of the final data check will be reported to other laboratories either in the form of a new copy of tables which replaces tables earlier distributed or by sending a letter about the changes if they are not extensive. These tables replace the preliminary fortnightly data, too. In agreement with other laboratories the quarterly data can be obtained on other input media directly suitable for a computer in exchange with their own data in the same form. The quarterly data are available at least four weeks after the end of the quarterly period.

X. CONCLUSION

The test program run on the computer TESLA 270 shows that:

— all the measured values are tested;

— the measured values not acceptable for any reason are set to zero. Zero values replacing submits to the manual test;

— manual test are restricted to a few values, which facilitates the work of the laboratory assistant;

— more rigorous checking and stability testing make greater demands on the run-time. According to the present experience the run-times of the programs are:

PRETEST 15 minutes; *PREDIST* depends on the required number of copies;

SNAKES 25 minutes; *PCOF* 3 minutes; *DISTNM* depends on the required number of copies; *DISTPR* depends on the required number of copies; *RATIOS* depends on the required number of copies; *NMTEST* 10 minutes.

The programs are written in ANSI FORTRAN as long as the machine representation TESLA FORTRAN permits it. Program implementation by other computers means the transcription of several FORTRAN statements in the new machine representation.

Data inputs are always organized through subroutines. It is strictly stated in which array which information should be placed. When the read information changes, only the input subroutines are changed, the remaining parts of the program are independent.

Programs are written in a modular way — the individual tasks are divided into as many subroutines as possible.

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