Calibration of the Sanae and Hermanus Neutron Monitors

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Abstract

Two calibration neutron monitors were completed in September 2002. One was used to calibrate the Sanae and the Hermanus neutron monitors, while an accompanying paper discusses the performance of the other calibrator on its voyage with the US/Australian neutron monitor to Antarctica.

1. Introduction

At the 27th ICRC in 2001, plans were described by Moraal *et al.* (2001) to construct a mobile neutron monitor to intercalibrate the world's network of neutron monitors (NM). The main objective of this intercalibration is to derive energy spectra of the cosmic ray intensity above the atmosphere from differential response functions. This will increase the spectral information about cosmic ray modulation to at least one decade higher in energy than is presently available. The design specification was to calibrate NM count rates to within ±0.2% to produce useful spectra. The requirements for, and the expected performance of such a calibrator were described in detail in that paper. Two of these NMs were completed in September 2002, with the final design described in the accompanying paper. A full description of the calibrator can be found at http://www.puk.ac.za/physics/Physics%20Web/Research/Cal%20NM.htm

2. Calibration of the Sanae Neutron Monitor

The Sanae NM is a 6 counter standard NM64 design, built inside the SANAE base of the South African National Antarctic Programme at Vesleskarvet, Antarctica. It is 1220 m above sea level, at geographic coordinates 71° South, 2° West, and at cutoff rigidity 0.79 GV. Nine calibrations of approximately 1 million counts each were done in three different positions between 19 December 2002 and 2 February 2003. Three calibrations were done in each of these three positions to test repeatability. Position 1 was 1.5 m Southeast of the 6NM64 and 1.7 m below it. Position 2 was 1.6 m South of the 6NM64 and 0.45 m higher. Position 3 was outside the base, on the western balloon launching platform, about 2 m from the wall of the base, and on the same level as the 6NM64.

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Table 1. Counting Ratios (6NM64/Calibrator)

Position	Run 1	Run 2	Run 3	Average
1	53.523 (-0.51%)	53.660 (-0.23%)	54.151 (+0.74%)	53.778
2	50.846 (+0.22%)	50.719 (-0.03%)	50.638 (-0.19%)	50.734
3	50.848 (+.006%)	50.768 (-0.30%)	50.919 (+0.15%)	50.845

Table 2. Measured Standard Deviation/Poisson Deviation

Calibration	Pressure	Uncorrected		Corrected	
Number	Range (mb)	Calibrator	6NM64	Calibrator	6NM64
1	18	1.34	3.93	1.23	1.79
5	15	1.28	3.34	1.26	1.72
7	15	1.27	2.97	1.24	1.74
8	12	1.26	3.31	1.23	1.70
3	11	1.26	2.94	1.22	1.54
6	10	1.27	2.83	1.27	1.63
9	6	1.23	2.22	1.17	1.89
4	6	1.25	2.04	1.25	1.61
2	4	1.25	1.78	1.26	1.97
Average		1.267	2.760	1.237	1.732

The recorded counting ratios (6NM64 Counts/Calibrator Counts) are shown in Table 1. The last column is the average calibration for all three runs at that position. The percentage differences are the deviation from the average at each position, shown in the last column. The statistical plus systematic fluctuation for each calibration is estimated to be ±0.14%, as described in the next paragraph. This shows that the calibration at position 1, with deviations as large as -0.51% and $+0.74\%$, was unsuccessful. The reason is that this position was in the shadow cast by a moving, heavy crane which caused a varying environment. For the remaining six calibrations in positions 2 and 3, the largest deviation form the average is 0.30%. The averages in the last column contain three times the number of counts, and we estimate that their deviation will therefore not be more than $0.3\%/\sqrt{3} \approx 0.2\%$. This meets the design specification for the calibration.

The statistical deviation of the counting ratios was determined as follows. The calibrator counted 10^6 counts per calibration which gives a Poisson deviation of 0.1%. Since the 6NM64 counts 50 times as much, its deviation should be $0.1\%/\sqrt{50} = 0.014\%$. Table 2 shows that the actual one standard deviation was considerably higher than this amount. It is higher for the 6NM64 than for the calibrator, and it is highest for calibrations during which there were large pressure fluctuations. These pressure fluctuations cause fluctuations in the counting rate above the statistical fluctuation, and this effect will be largest on the monitor with the highest counting rate (the smallest statistical fluctuation). The last two

Table 3. Temperature Corrected Counting Ratios

Position	Run 1	Run 2	Run 3	Average
1	53.107 (-0.27%)	53.087 (-0.31%)	53.534 (+0.58%)	53.242
2	50.484 (+0.26%)	50.274 (-0.15%)	50.294 (-0.11%)	50.351
3	49.554 (+0.28%)	49.223 (-0.38%)	49.468 (+0.10%)	49.415

columns show the standard deviation after pressure corrections. These numbers are fairly stable and consistent, and their average is given in the last two lines. They are still larger than one, mostly due to the multiplicity effect described by Hatton (1971), and fluctuations in the primary intensity above the atmosphere. From these considerations the standard deviation on each calibration containing 1 million counts is, therefore,

$$\sqrt{[1.237^2 + (1.732/\sqrt{50})^2]} * 0.1\% = 0.14\% \tag{1}$$

Notice from Table I that the calibrator counts *less* outside the base at position 3 than inside at position 2. It was discovered that this is due to the temperature difference between the 6NM64 and the calibrator when the latter stands outside. Figure 1 shows the counting ratio as function of the temperature difference between the two monitors. It has a large temperature coefficient of 0.13%/°C. This effect is purely instrumental in nature, because the two monitors experience identical atmospheric conditions. This temperature coefficient is three times larger, and in the opposite sense than the well-known atmospheric coefficient of $-0.03\%/^\circ$C, given by Iucci *et al.* (2000). All the ratios were corrected with this amount, and Table 3 shows these temperature corrected ratios. From the average of positions 2 and 3, it now follows that the counting rate outside the base is indeed higher, and that the roof and building absorb an amount of (50.351-49.415)/49.015 = 1.91% of the intensity. This small amount is quite consistent with the thin, lightweight fibreglass material of the base walls and roof.

3. Summary and Conclusions

The Sanae neutron monitor was successfully calibrated according to prespecified standards, and its normalization is 50.845± 0.102 times the calibration standard. For eventual comparison with other neutron monitors, the calibrator's absolute count rate at that point must be increased with 1.91% to correct for the roof of the base. The calibrator was brought to the Hermanus neutron monitor for a second calibration from 14 February until 6 May 2003. The preliminary result is that the 12NM64 monitor at Hermanus counts 106.84 times more than the calibrator. The quality of the calibration was however not the same as that of the Sanae neutron monitor, and this number must be regarded as very preliminary. The latitude and altitude response of the calibrator's count rate will be measured

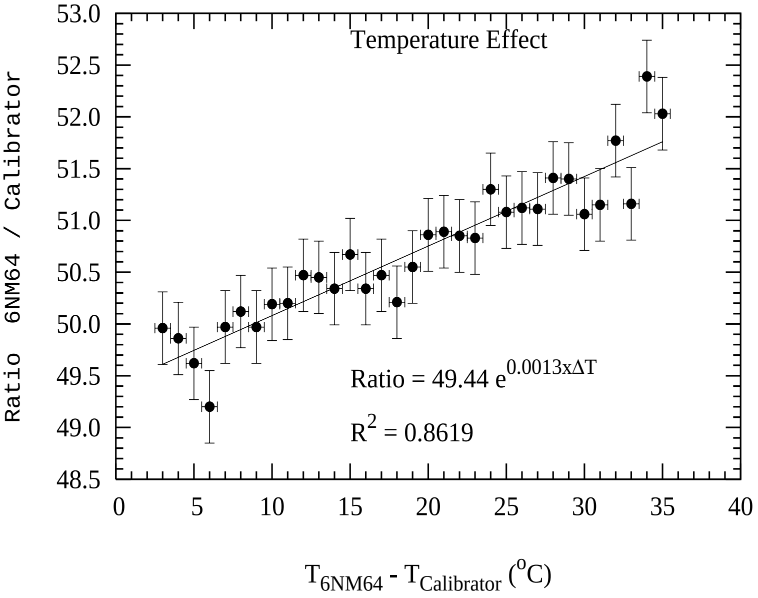

Fig. 1. Ratio of 6NM64 to Calibrator counting rate as function of temperature difference between the monitors. The temperature coefficient is 0.13%/°C.

further during the next year as described in the accompanying paper, and when this is known accurately enough, the two numbers mentioned above can finally be related to one another.

4. Acknowledgements

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5. References

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