**ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH**

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Technical Inspection and Safety Division

Divisional Report

CERN-TIS-2002-015-RP-CF

**Investigations of a Recombination Chamber as a Mixed
Field Dosimeter in Comparison with a Tissue-Equivalent
Proportional Counter at CERF**

Sabine Mayer, Thomas Otto

CERN, TIS-RP, CH-1211 Geneva 23, Switzerland

Abstract

A comparison of two types of dose equivalent meters, a recombination chamber REM-2 and a tissue-equivalent proportional counter HANDI, were carried out at the CERN-EC high energy reference field facility, CERF, in October 2001. Here, the mixed high-energy radiation field in commercial flight altitudes can be simulated with dose equivalent rates up to 2 orders of magnitude higher. The total absorbed dose and the dose equivalent have been measured at different radiation field intensities. Of particular interest for measuring in the CERF field is the assessment of the low LET-component, i.e. the gamma and muon components of the field, which are not taken into account by existing Monte Carlo simulations modeling the radiation field. The new results for the estimation of the low LET-component are compared with previous ones delivered by REM-2 at CERF. The results show good agreement between the REM-2 chamber and the HANDI.

Presented at the conference

RMA, 10th Symposium on Radiation Measurements and Applications, 21-23 May 2002,
Michigan, USA

CERN, 1211 Geneva 23, Switzerland
9 July 2002

1. Introduction

Investigations of the suitability of a recombination chamber REM-2 in comparison with a tissue-equivalent proportional counter HANDI to measure dose equivalent and absorbed dose were made at the CERN-EC High Energy Reference Field Facility (CERF-field) [1]. The CERF-field is used for testing detectors to be used around high-energy particle accelerators and is in addition sufficiently similar to the cosmic ray field encountered at commercial flight altitudes. The neutron component of the field is well characterised by measurements with a wide range of active and passive detectors, and by Monte Carlo simulations carried out at CERN [2,3]. Unfortunately the Monte Carlo simulations only model radiation produced in the target, so are not relevant for the concurrent γ and muon components of the field originating from other beam lines and long-lived activation products. Hence it is difficult to interpret the obtained results with the simulations. At this time at CERN only the HANDI-TEPC is used to actually measure the total dose. For this reason the results of the recombination chamber are compared with the HANDI-TEPC.

2. Material and Methods

2.1. Recombination Chamber REM-2

The recombination chamber REM-2 [4], manufactured in Poland by POLON-Bydgoszcz is a cylindrical, parallel-plate ionisation chamber with 25 tissue-equivalent electrodes. The chamber is filled with a mixture of methane and nitrogen (5%) at a pressure of about 1 MPa. It has a volume of 2000 cm³, a mass of 6 kg and an effective wall thickness of about 2 g/cm².

The chamber is used in a mode where the ion collection efficiency is governed by the initial recombination of ions. Here, the ion density along the tracks of primary and secondary charged particles determine the degree of initial recombination and this fact can be related to the LET of the ions and hence to the radiation quality.

In order to evaluate the dose equivalent, a method proposed by Zielczynski et al. [5] is used, where the ionisation currents measured at a recombination voltage U_R and a high voltage guaranteeing saturation U_S are compared. The recombination voltage was adjusted before during a calibration procedure [6] in a way that 4% of ions recombine (i.e. ion collection efficiency is equal to 0.96) when the chamber is irradiated in a reference gamma field (¹³⁷Cs source).

2.2. HANDI-TEPC

The Homburg Area Neutron Dosimeter (HANDI) [7] is a portable instrument based on a low pressure tissue-equivalent proportional counter (TEPC). The spherical TEPC has a wall thickness of 0.15 g/cm² and is filled with propane based tissue equivalent gas mixture simulating a tissue sphere of density 1 g/cm³ with a diameter of 2 μ m. Using pulse-height analysis this instrument measures in real time absorbed dose as well as lineal energy, y , in the dynamic range from 0.05 up to 1500 keV/ μ m [8]. The quality factor is determined from the y -distribution of absorbed dose. The system is calibrated in a ⁶⁰Co gamma field in terms of absorbed dose in tissue.

Due to their construction and operational principle, neither the REM-2 chamber nor the HANDI-TEPC indicates exactly the ambient dose equivalent $H^*(10)$. They both measure a dose equivalent quantity H_{tot} . The instruments are calibrated in terms of $H^*(10)$ with γ -radiation, therefore they will also indicate this quantity for mixed radiation fields in good approximation.

2.3. CERN-EC High Energy Reference Field Facility (CERF-field)

The CERF-field is situated on one of the secondary beams from the Super Proton Synchrotron (SPS) [1]. A pulsed hadron beam with a momentum of 120 GeV/c, a period of 16.8 s and a pulse length of 5.1 s is fired onto a copper target in a radiation cave. The resulting secondary particles emitted under 90° are filtered through either 80 cm of concrete or 40 cm of concrete side shielding, giving almost uniform radiation fields over two 2 x 2 m² areas. These are divided into grids denoted as CTx (concrete top, position number x) or CSx (concrete side, position number x). The intensity of the beam was monitored by an air-filled precision ionisation chamber (PIC) at atmospheric pressure, placed in the beam just upstream of the target and connected to a current-digitising circuit. One PIC count corresponds to $(2.3 \pm 0.1) \cdot 10^4$ particles [9].

3. Measurements

Measurements at the CERF-field were carried out with the REM-2 chamber at different intensities at position CT6 and CS3. For position CT6 also measurements without target at two different intensities have been made.

In 1998, Golnik et al. [10,11] determined the absorbed dose due to the concurrent γ and muon radiation using a plot, where the total dose per spill is a function of beam intensity. The same method applied to the results of October 2001 leads to a concurrent dose of 170 ± 20 nGy per spill (Fig. 1) by extrapolating to zero-intensity. The measurements without target also contain the assessment of the concurrent dose. As it can be seen from the Fig. 1 the concurrent dose measured without target agrees very well with the value determined with the method of Golnik. At the side location we don't observe concurrent radiation. Here the linear fit passes through the origin of the coordinate system.

Fig. 1. Total absorbed dose per spill measured at different intensities of the beam on the target for the REM-2 chamber. The results are given for the CT6 position on concrete roof (rhombi), for CT6 position without target (circle) and the CS3 concrete side position (triangles).

In Table 1 we list the absorbed dose per spill due to concurrent radiation (background radiation) determined earlier with the recombination chamber. In the measurement of October 2001 a slightly higher background radiation was observed.

Table 1

Absorbed dose per spill due to the concurrent (background) radiation. Values for the years 1993-1998 are taken from Golnik et al. [10]. The value of 2001 is determined from Fig. 1.

CERF – run	1993 (Sept.)	1997 (Sept.)	1998 (April)	2001 (Oct.)
Absorbed dose per spill [nGy]	140 ± 20	137 ± 7	125 ± 10	170 ± 20

Fig. 2. Total absorbed dose per spill versus beam intensity per spill for the HANDI-TEPC. The results are given for the concrete top position CT6 (rhombi) and the concrete side position CS4 (triangles). One measurement on the roof concrete CT6 was done without target. (circle)

Fig. 3. H_{tot} per PIC count for the concrete top position CT6 measured with the HANDI-TEPC (●) and the REM-2 chamber (○) at different beam intensities on the target.

For comparison HANDI measurements were done at the concrete roof position CT6 and at the concrete side position CS4 at slightly different intensities. In Fig. 2 the measured total absorbed dose per spill is displayed relative to the beam intensity to determine as before the concurrent radiation using the HANDI-TEPC results. This leads to a value of 180 ± 10 nGy per spill, which matches very well with the value determined with the REM-2 chamber. The measurement point without target confirms also the determined value.

In Fig. 3 the dose equivalent quantity H_{tot} per PIC count versus beam intensity on the target is compared for the HANDI-TEPC results and the results of REM-2 chamber with the $Q(L)$ -relationship from ICRP 60 [12]. Due to the concurrent γ and muon radiation the absorbed dose per PIC count exhibits a non-linear dependence versus beam intensity at the top location. Between the instruments a very good agreement can be asserted.

4. Conclusions

The measurements confirm the presence of a detectable contribution of low LET radiation at CERF. The determination of the “concurrent” low LET radiation showed good results in comparison to the measurements in 1998 and there was a good agreement between the results of the HANDI and the REM-2 chamber. Presenting results for the CERF-field it is very important to indicate the beam intensity on the target. For devices that show sensitivity to low LET radiation the concurrent γ and muon components of the field have to be considered.

References

- [1] A. Mitaroff, M. Silari., Report CERN-TIS-2001-006-RP-PP, 2001.
- [2] C. Birattari., T. Rancati., A. Ferrari, M. Höfert, T. Otto, M. Silari, in: Proceedings of the Third Specialists Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities, Tohoku University, Sendai, Japan, 12-13 May 1997, pp. 219-234, 1997.
- [3] S. Roesler, G.R. Stevenson, CERN/TIS-RP/IR/93-47, 1993.
- [4] N. Golnik, Raport IAE-20/A, Institute of Atomic Energy, 05-400 Otwock-Swierk, Poland, 1996.
- [5] M. Zielczynski, N. Golnik, Radiat. Prot. Dosim. 52, 419-422 (1994)
- [6] F. McLay, S. Mayer, T. Otto, CERN/TIS-RP/TM-2001-038, EDMS document No. 331552, 2001.
- [7] A. Kunz, E. Arend, E. Dietz, S. Gerdung, R.E. Grillmaier, T. Lim and P. Pihet, Radiat. Prot. Dosim. 44, 213-219 (1992)
- [8] T. Lim, J.F. Bottollier-Depois, J.G. Festag, N. Golnik, R.E. Grillmaier, M. Höfert, L. Lindborg, SPIE Vol.. 2867, 300-305 (1997)
- [9] E. Gschwendtner, A. Mitaroff, L. Ulrici, CERN/TIS-RP/IR/2000-09, 2000.
- [10] N. Golnik, Raport IAE-34/A, Institute of Atomic Energy, 05-400 Otwock-Swierk, Poland, 1998.
- [11] N. Golnik, M. Silari., T. Otto, Radiat. Prot. Dosim. 86, 175-179 (1999)
- [12] International Commission on Radiological Protection, ICRP Publication 60, Pergamon Press, Oxford, ISBN 0080411444, 1991.