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COMPARISON OF PERSONNEL MONITORING SYSTEMS IN THE RADIATION ENVIRONMENT OF HIGH ENERGY ELECTRON ACCELERATORS

F. LUCCI, M. PELLICCIONI

CNEN, Laboratori Nazionali di Frascati, Italy

S. PSZONA and B. SNOPEK

Institute of Nuclear Research, Świerk Otwock, Poland

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An intercomparison of a personnel monitoring system realized by neutron film-badges and TLDs has been undertaken with a new technique which is based on the recombination method for the dose equivalent determination. The measurements were carried out in mixed neutron and gamma fields near two high energy electron accelerators. The results of the intercomparison show an acceptable agreement between the two systems. The dose equivalent determination by nuclear emulsion – TLD method gives in fact a 30% underestimation at the most, wich satisfies the radioprotection requirements.

1. Introduction

The radiation environment of high energy electron accelerators at Frascati has been examined by Pszona et al.[1]) and the mean quality factor for most of the investigated places was found to be between 2–5. Neutrons generated through (γ,n) processes with shielding materials and accelerator structures are the component of radiation responsible for such high values of the quality factors. The initial energy spectrum of neutrons generated mostly through (γ,n) reactions in the "giant resonance" region is strongly modified due to scattering and nuclear reactions in the shielding. It is very likely that a considerable part of the energy spectrum of neutrons is below 500 keV, i.e. below the sensitivity threshold of NTA nuclear emulsion, which is used for personnel neutron monitoring and the possible errors of dose equivalent determination would be large. Thus the intercomparison of the personnel monitoring system used at Frascati has been undertaken with a new technique developed at the Institute of Nuclear Research (Świerk) which is based on the use of the "recombination" method of dose equivalent determination. The results of this intercomparison are presented in this paper.

2. Description of personnel monitors used for intercomparison

The personnel monitoring system used at Frascati for this intercomparison is composed of:

a) NTA neutron films calibrated against an Am–Be or ^{252}Cf neutron source.

b) TLD–CaF_2 made by MBLE for gamma radiation.

The new system proposed for personnel dose equivalent determination in mixed fields is based on the "recombination" method using TE ionization chambers. For personnel monitoring three TE pocket size ionization chambers in a set as seen in fig. 1 were used. The outer chambers of the set are operated in saturation condition under a pressure of 1.2 kg/cm^2 of TE gas. The condition for columnar recombination is created in the middle chamber operated under a pressure of 5 kg/cm^2. If an appropriate electric field strength is selected the response of the chamber operated in columnar recombination regime is a linear function of the quality factor of detected radiation. From the set the absorbed dose and the quality factor can be determined. The details of the method were described by Zielczynski and Pszona[2]).

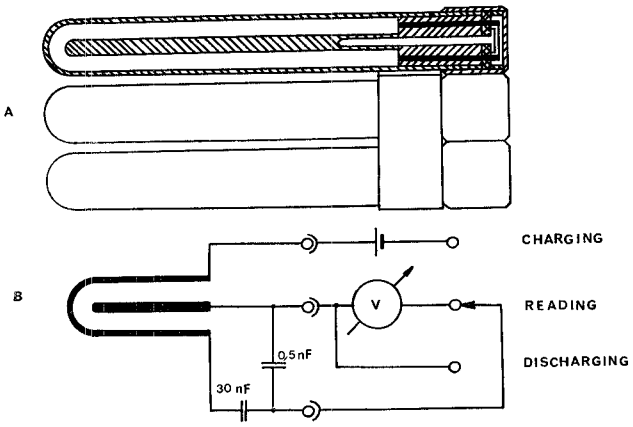

Fig. 1. (A) Three TE chamber Rem-meter construction. (B) Supplying and charge reading circuit.

TABLE 1

Results of measurements with Am–Be and Am-B neutron sources.

TLD (mR)	NTA film (mrem)	DE (mrem)	$Q_{app} = DE/D$	Recombination set D (mrad)	$\bar{Q}$	H (mrem)	Comments
40	1150	1190	4.8	250	5.5	1370	Am–Be shielded with 8 mm of lead
5	165	170	5.7	30	9.0	270	Am–B shielded with 4 mm of lead

TABLE 2

Results of measurements in the unshielded areas near the 1 GeV synchrotron.

TLD (mR)	NTA film (mrem)	DE (mrem)	$Q_{app} = DE/D$	Recombination set D (mrad)	$\bar{Q}$	H (mrem)	Comments
80	290	370	3.1	120	4.0	480	Middle of accelerator ring in a shadow
220	170	390	1.7	220	2.2	480	Middle of accelerator ring
110	170	280	1.5	180	1.1	210	Experimental hall 1 m from a deflecting magnet

3. Results and discussion

Detectors used at intercomparison were placed on the front of a phantom made of polythene 30 cm diam. × 60 cm high, filled with water.

The following three series of measurements were carried out:

a) with neutron sources: Am–Be and Am–B shielded by few mm of Pb;
b) in unshielded areas near the 1 GeV electron synchrotron;
c) in shielded areas near the 1 GeV electron synchrotron and the 400 MeV linear electron accelerator (LEALE).

The results of the intercomparison in the fields of the shielded neutron sources are shown in table 1. For the purpose of comparison of the results the dose equivalent determined with the recombination system will be indicated as H, while the dose equivalent valued from NTA+TLD readings will be indicated as DE. An "apparent quality factor" is also indicated, which was deduced from NTA+TLD readings as $Q_{app} = (NTA+TLD)/D$, where D is the absorbed dose determined by TE ionization chambers used in the recombination set.

An underestimation of the dose equivalent by the NTA+TLD system is noticed, probably due to modification of neutron spectra through passage in lead as compared with the calibration spectrum. In the case of the Am–B source the indications of NTA films are as low as 60% of the response of the recombination set. The mean quality factor $\bar{Q}$ determined by the recombination set is 5.5 for Am-Be shielded against low energy γ-rays of ^{241}Am, while for Am–B the mean value of Q is 9. This is the result of the difference in neutron spectra and the difference in contribution of γ-rays from the excited nucleus after (α,n) reactions on Be and B.

In unshielded areas of the 1 GeV electron accelerator three points were selected for measurements: inside and outside a shadow of concrete blocks in the middle of the ring at the level of the basement and in the experimental hall 1 m from a deflecting magnet. The results shown in table 2 indicate that the dose equivalents determined by both systems agree within about ±30%, which can be assumed as satisfactory from the point of view of radiation protection. Q_{app} follows the tendency of the mean quality factor determined by the recombination method. In the middle of the ring the mean quality factor may reach even 4 when the phantom is placed in a shadow of concrete blocks. The radiation field near the beam as in the experimental hall, is composed mainly of γ-rays ($\bar{Q}$ is close to 1).

When $\bar{Q}$ is close to 1, a tendency to overestimate the

TABLE 3

Results of measurements in the shielded areas of electron accelerators.

TLD (mR)	NTA film (mrem)	DE (mrem)	$Q_{app} = DE/D$	Recombination set D (mrad)	$\bar{Q}$	H (mrem)	Comments
20	160	180	4.0	45	5.0	215	LEALE target: tungsten
20	160	180	4.5	40	4.0	160	0.3 mm
110	340	450	3.2	140	4.0	560	Synchrotron, on the roof

dose equivalent from NTA films is noticed which could be assumed to be due to the presence of a high energy neutron component or to the influence of the (γ,p) reaction in the film badge on DE readings.

The results in shielded areas are shown in table 3. The synchrotron measurements were carried out on the roof of the machine. The mean Q (as well as Q_{app}) is close to 4 and dose equivalent values by both methods agree within 30%. The same picture is observed for the area near the target room at LEALE where the mean quality factor is between 4 and 5 which correspond well to the previous measurements made with portable instruments[1]).

4. Conclusions

The results of intercomparing the two systems, one of which (i.e. recombination set) has a true response to any mixture of radiation, are summarized in figs. 2 and 3. In fig. 2 the values of the quality factor are compared, while fig. 3 refers to the dose equivalent results. From the comparisons a general picture seems to indicate that near high energy electron accelerators the dose equivalent determination by nuclear emulsion methods

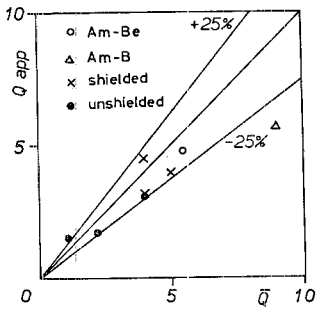

Fig. 2. Comparison of the mean quality factor by recombination system with Q_{app}.

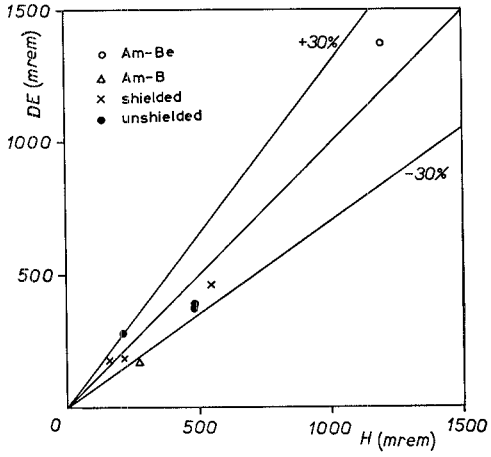

Fig. 3. Comparison of the dose equivalent values determined with the two systems.

give an underestimation of about 30% at most, which can be fully acceptable for radiation protection purposes. The expected large contribution of neutrons below 500 keV in the dose equivalent was not justified, which in turn means that the neutron spectrum after shielding is similar enough to the calibration one.

The radiation fields around high energy electron accelerators can contain a considerable fraction of neutrons affecting the mean quality factor which attains even 5 at several points.

References

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[2]) M. Zielczynski and S. Pszona, A personal dose equivalent meter for mixed radiation, Report CERN 71-16 (1971) p. 403.