NEW DOSIMETRIC INSTRUMENTS BASED ON A RECOMBINATION CHAMBER

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INTRODUCTION

Three prototypes of new dosimetric devices were recently developed for different purposes of radiation protection in mixed radiation fields. The REM-2 high pressure tissue equivalent ionization chamber serves as the detector in all the systems described. The operation of the chamber under conditions of initial recombination of ions enables evaluation of radiation quality in radiation fields of unknown composition.

RECOMBINATION CHAMBER

The REM-2 chamber contains 25 tissue-equivalent electrodes, which form 12 parallel sections (1). The electrodes are 12 cm in diameter and 3 mm thick. The distance between electrodes is 7 mm. Total mass is equal to 6.5 kg. The effective wall thickness of the chamber is equivalent to about 1.8 cm of tissue and the gas cavity volume is of about 2000 cm^3. The chamber is usually filled, up to about 1 MPa, with a gas mixture consisting of methane and 5% of nitrogen. The central rod connects 12 collecting electrodes. The polarizing electrodes are connected alternately to one of two side rods and thus form two sets of electrodes. The chamber can be used in different operating modes. Two of them are important for the devices considered:

1) The *saturation* mode, when the voltage ensuring near saturation conditions (1200 V) is applied to both sets of the polarizing electrodes. This mode is used for determination of the ambient absorbed dose, $D^*(10)$ of mixed radiation. The sensitivity of the chamber in this mode is equal to 100 $fA/\mu Gy{\cdot}h^{-1}$.

2) The *differential* mode, when the saturation voltage is applied to one set of the polarizing electrodes and the recombination voltage of opposite polarity is applied to the another one. This mode ensures direct proportionality of the charge collected on the measuring electrodes to the ambient dose equivalent of mixed radiation of any composition. The sensitivity of the chamber operated in this mode equals to 2 $fA/\mu Sv{\cdot}h^{-1}$.

MICROCOMPUTER CONTROLLED DOSE EQUIVALENT RATE METER

It was shown earlier (1-3) that the ionization chamber of REM-2 type may serve as a good detector of $H^*(10)$, with weak dependence on neutron energy (see Fig. 1).

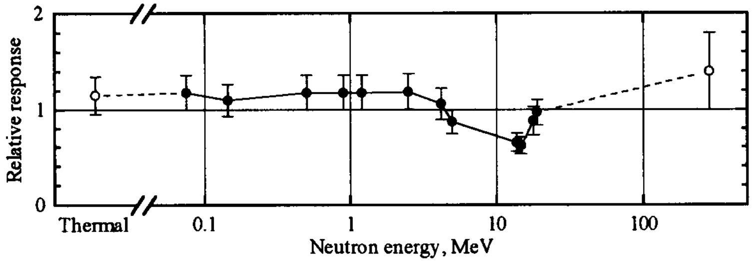

Figure 1. Relative response of the REM-2 recombination chamber to H*(10) versus neutron energy (1)

Now a laboratory set-up was designed (1), which can be considered as a prototype of a microcomputer controlled dose equivalent rate meter, based on a recombination principle and intended for routine use in radiation protection. The device consists of: a recombination chamber REM-2, a monitoring chamber, and an electronic circuit connected to a personal computer and controlled by special software for the measurement control, data collecting and on line processing.

The basic circuit of the device is shown in Fig. 2. Additionally to the main measuring channel with the REM-2 chamber it contains also the monitoring channel with the second chamber M. The monitoring is necessary if the radiation field is unsteady i.e. when the mean dose rate changes more than 1% during the time of measurements, which is of order of minutes.

The dose equivalent is proportional to the amount of recombination, so it can be determined by comparison the ionization currents collected at two different collecting voltages applied to the chamber. In our device the sequential application of the voltages to the chamber is controlled by the computer. The high-stability voltage unit U_{CTRL} is used as the voltage source. Its output voltage is exactly 200 times higher than the control voltage given by the analog output of the DAC computer card.

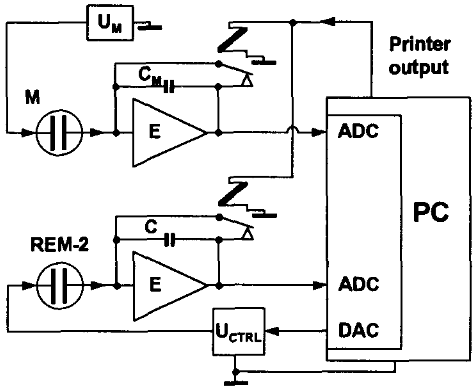

Figure 2. Principle circuit of the ambient dose equivalent meter (1).
REM-2 - recombination chamber, U_{CTRL} - externally controlled high voltage supply unit, E - electrometer, PC - personal computer with ADC/DAC card, M - monitor chamber, U_M - steady voltage unit.

Ionization current is measured by the electrometer E operated in an integrating mode. Ions collected on the electrodes of the chamber charge the integrating capacitor C during an appropriate time interval. The output voltages are measured using the analog input of the computer card (ADC). The 5 V signal from the printer output of the computer is used for discharging of the capacitor C and for shortening of the electrometer at the time of the voltage change-over.

The basic measuring range of the dose rate is from $\dot{D}^*(10)$ = 25 μGy/h up to 250 μGy/h, and the whole range - from 1 μGy/h to 0.25 Gy/h, which corresponds to the values of $\dot{H}^*(10)$ from 1 μSv/h up to about 1 Sv/h. The accuracy of measured values of $\dot{D}^*(10)$ and of $\dot{H}^*(10)$ depends primarily on energy characteristic of recombination chamber and on dose rate. Usually, it is better than 10% for $\dot{D}^*(10)$ and better than 20% for $\dot{H}^*(10)$, in the basic range of dose rates. Accuracy of $\dot{H}^*(10)$ in the whole range of dose rates and energy covered by the device is within a factor of two.

SYSTEM FOR IN-FLIGHT AND LOW-LEVEL DOSIMETRY

The minimum detection level, stated in the technical manual of the REM-2 chamber is 10 μGy/h for the saturation mode and 500 μSv/h for the differential mode. These values do not satisfy the requirements of in-flight dosimetry. The problem can be solved by use of the self-contained measuring system (4), shortly described below (see Fig. 3).

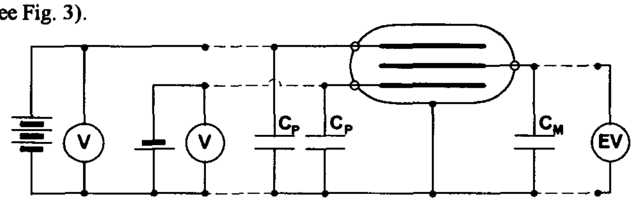

Figure 3. Self-contained measuring system. Broken lines show connections performed before and after irradiation.

The system consists of recombination chamber with three capacitors. The distortion charge is compensated by use of a special procedure for charging the supplying capacitors and for reading the voltage on the measuring capacitors. The signal measured by the system is proportional to $H^*(10)$.

Before the flight the capacitors C_P should be charged to the voltage U_{P0} at known temperature T_0. It was shown that the charge collected on the measuring capacity C_M does not depend on course of changes of the polarizing voltage and temperature and is proportional to the absorbed dose if the temperature of the chamber at the time of read out of the voltage on the measuring capacity is equal to T_0 and the voltage between the chamber electrodes is equal to U_{P0}. Therefore, after the flight the irradiated measuring system should be placed in laboratory conditions at the temperature T_0 for sufficiently long time. Then the polarizing capacity should be connected to a source of voltage, exactly equal to the initial voltage U_{P0}.

Provisional results indicate that our system gives possibility to measure the $H^*(10)$ of order of some μSv with uncertainty ca. 25% in any field of penetration radiation, with an integration time up to some days. Investigations of the performance characteristics of the system are under progress.

ANALOG METER OF QUALITY FACTOR

In this device (5), the modified recombination chamber, denoted REM-2Q, serves as a detector. The modification lies in the change of the interelectrode spacing such that two parts of the differential recombination chamber are not equal: the ratio of their volumes equals to about 0.9. The device enables direct determination of the radiation quality factor (QF) in mixed radiation fields.

The operational principle of the QF-meter is shown in Fig. 4.

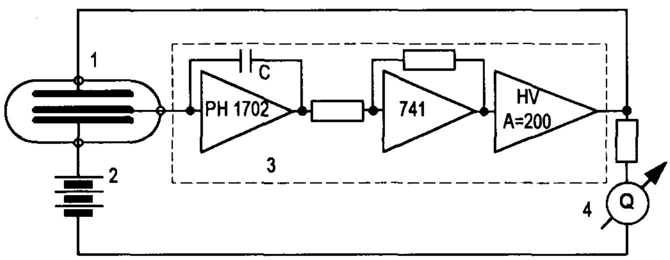

Figure 4. Functional circuit of the QF-meter: 1 - recombination chamber; 2 - high voltage source; 3 - high voltage electrometrical amplifier; 4 - voltmeter calibrated in units of quality factor.

When the chamber is placed in a radiation field, almost all the positive ions created in the smaller volume of the chamber, are collected to the middle electrode and charge the capacity C. This causes an increase of the negative voltage at the output of the high voltage amplifier. This voltage is applied to the electrode supplying the larger volume of the chamber. Therefore some negative ions from the larger volume can also reach the collecting electrode, reducing the effective current charging capacity C. An equilibrium voltage of the upper electrode is established when the resulting ionization current through the collecting electrode is equal to zero, i.e. when the ratio of the ion collection efficiencies in the larger and smaller parts of the chamber is equal to the volume ratio of the chamber. The recombination chamber works under conditions of local recombination of ions, so the value of the equilibrium voltage depends on LET and is approximately proportional to the radiation quality factor, as defined in ICRP Report 21.

ACKNOWLEDGEMENTS

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REFERENCES:

1. M. Zielczyński, N. Golnik. and Z. Rusinowski,. in print *Nuclear Instruments and Methods A*.
2. N. Golnik and M. Zielczyński, In: *Proc. 17th IRPA Regional Congress on Radiological Protection*, Portsmouth 6-10 June 1994, (Nuclear Technology Publishing, Ashford, Kent) pp 93-96 (1994).
3. N. Golnik, Recombination Methods in Dosimetry of Mixed Radiation. *IAE (Swierk, Poland)* (in print).
4. M. Zielczyński, N. Golnik and S.V. Shvidkij, in print *Nukleonika*.
5. M. Zielczyński and N. Golnik, Nukleonika Vol.38, No.1, pp.23-30 (1993).