A DOSE-EQUIVALENT RATE METER FOR ENVIRONMENTAL RADIATION SURVEYS

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INTRODUCTION

In 1969 a scintillation dose rate meter was developed |1| which is well suited for measuring the exposure rate for photon energies above 20 keV. The air equivalent response of the scintillation detector is achieved by coating the plastic scintillator (NE 102A) in the probe with a thin layer of ZnS |1|, |4|.

In report 39 |2| ICRU recommended new quantities for measurements in radiation protection with external sources. For environmental monitoring, these quantities are the ambient dose equivalent H*(10) and the directional dose equivalent H'(0.07). If these new quantities are introduced for practical measurements in radiation protection, instruments must be modified to directly indicate the ambient dose eqivalent or the directional dose equivalent.

In 1986 the PTB began carrying out experimental investigations to ascertain whether the response of the scintillation detectors could be modified to obtain an indication of the ambient dose-equivalent rate independent of the photon energy. At the same time the electronics of these instruments was improved to overcome constructional shortcomings. The dependence of the reading on the temperature was reduced electronically and the influence of the dark current of the photomultiplier on the more sensitive ranges was diminished.

INDICATION OF THE AMBIENT DOSE-EQUIVALENT RATE WITH A SCINTILLATION DETECTOR

An energy independent reading of the ambient dose equivalent rate with a scintillation dose rate meter is achieved if the quotient of the output current of the photomultiplier and the ambient dose equivalent rate is independent of the photon energy.

As shown in |1| the response of the scintillation detector as a function of photon energy can be influenced by coating the plastic scintillator in the probe with a thin layer of zinc sulfide or other inorganic scintillators of appropriate thickness.

This technique is also applied to obtain the scintillation detector's response which is needed for an energy independent reading of the ambient dose equivalent rate. Research work has been carried out on the instrument which is suitable for measuring radiation levels in the order of those in the natural environment.

multiplier is high and the dark current is in the order of the signal current. This current also depends on the temperature and increases with increasing temperature.

To eliminate the dependence of the signal on the temperature, the gain of the photomultiplier must be controlled by the temperature of the photomultiplier-scintillator combination. The contribution of the dark current to the signal current can be reduced by subtracting its value.

All information needed for controlling the high voltage and the gain of the photomultiplier in all ranges as a function of temperature is stored together with information on the corresponding dark current in an EPROM. For each range and each measured temperature of the detector between -20 $^{\circ}$C and +40 $^{\circ}$C, this information is retrieved from the memory and used to control the high voltage supply and to subtract the corresponding value of the dark current from the signal current.

As it is impossible to measure the family of characteristics to be stored in the memory in a reasonably short time, P. Seyfried has developed a special algorithm |6| which allows the whole family of characteristics to be computed from a few measured values.

The first instrument equipped with this new system has shown temperature-dependent deviations in all ranges not exceeding a maximum value of + 5%. This could be improved by using more measured values to compute the family of characteristics.

LITERATURE

|1| Lauterbach, U.; Kolb, W.; Seyfried, P.: Ein empfindlicher Dosisleistungsmeser mit Szintillationsdetektor für Strahlenschutzzwecke. Bulletin SEV, 1970, 61, p. 1148.

|2| ICRU-Report 39, 1985: Determination of Dose Equivalents for External Radiation Sources. ICRU, Bethseda, Ma. 20814, USA

|3| Kolb, W.; Lauterbach, U: Ein Dosisleistungsmesser für die Messung der Umgebungsstrahlung. In: Rapid Methods for Measuring Radioactivity in the Environment, Wien, IAEA-SM-148/34, 1971, p. 565.

|4| Kolb, W.; Lauterbach, U.: A Scintillation Exposure Rate Meter for Environmental Surveys. In: Proceedings of the Natural Radiation Environmental II, USERDA, Symp. Series Report CONF-720805-Pl, 1974, p. 245.

|5| Großwendt, B.; Hohlfeld, K.; Kramer, H.M.; Selbach, H.-J.: Konversionsfaktoren für die ICRU-Äquivalentdosisgrößen zur Kalibrierung von Strahlenschutzdosimetern, PTB-Report, PTB-Dos-11, 1985.

|6| Seyfried, P.: Publication in preparation

DESCRIPTION OF GENERAL CIRCUIT

A schematic diagram of the dose rate meter, which consists of two parts, the detector probe and the control unit, is shown in Fig. 2. The instrument has 8 ranges from 30 nSv/h up to 100 µSv/h full scale which are selected either by the autoranging mode or by the manual mode. To avoid overloading of the photomultiplier, the output current of each range is limited to a maximum value of 3 nA by setting the high voltage of the photomultiplier to an appropriate value. This signal current, which is proportional to the dose rate, is indicated on the meter in the control unit. Selectable time constants are provided.

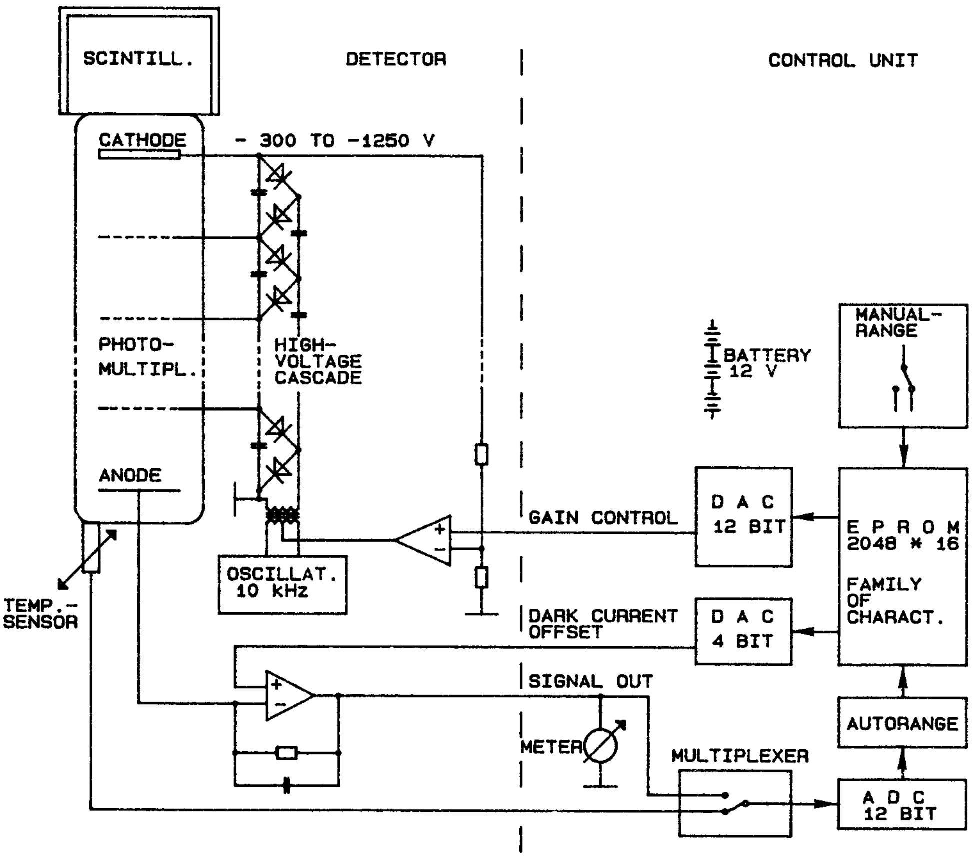

Fig. 2 Schematic diagram of the dose-equivalent rate meter

There are two disadvantages in this operation mode of the photomultiplier. With increasing temperature the signal current decreases for a fixed dose rate, and not only the amplification of the photomultiplier but also the fluorescence yield of the scintillator is dependent on the temperature. Besides this, the dark current of the photomultiplier may contribute to the signal current in the more sensitive ranges where the gain of the photo-

This instrument has a cylindrical plastic scintillator in the probe which is 75 mm in diameter and 75 mm in height |3|, |4|. In the course of the work various mixtures of inorganic scintillators containing ZnS, $CaWO_4$ and Gd_2O_2S were used to coat the cylindrical scintillator to obtain the desired response. The response of the scintillation detector was measured with X-reference radiation of series A |5| and γ-radiation of caesium-137 and cobalt-60. Dividing the readings of the dose-rate meter by the ambient dose equivalent rates at the same place in the calibration field yields the response of the instrument as a function of the photon energy. The ambient dose equivalent rate in the calibration field was calculated from the measured photon dose equivalent rate using the conversion factors given in |5|. The best approximation which we achieved to the desired response is shown in Fig. 1. From 20 keV up to 1.25 MeV the reading is within +4% and -20%, independent of the photon energy, normalized to the response at an energy of 662 keV.

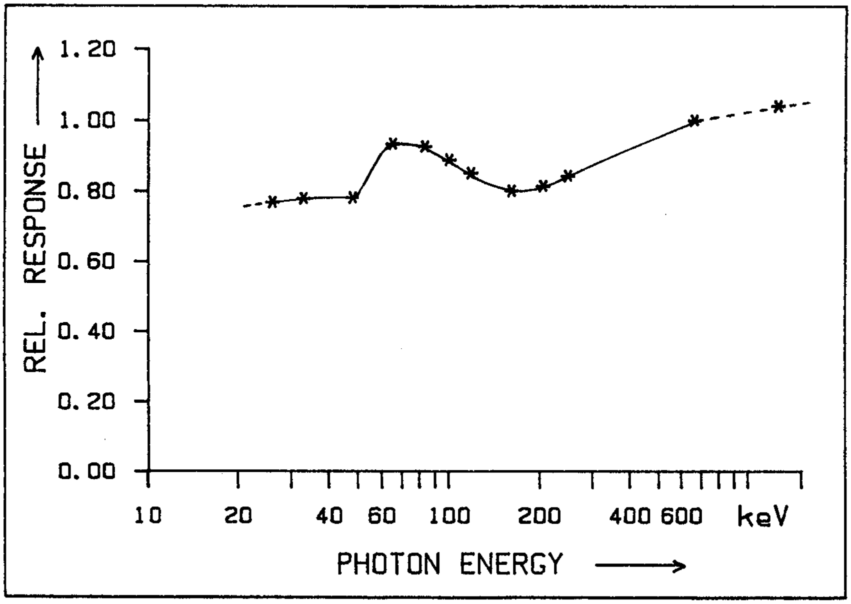

Fig. 1 Relative reponse of the dose-equivalent rate meter as function of the photon energy

As pointed out in |1| the decay time of phosphorescence after irradiation of the inorganic scintillators with X-rays should be within the order of a few seconds. Measurement have shown that 1 minute after irradiation, the yield of the phosphorescence is about $5 \cdot 10^{-4}$ of the intensity of the fluorescence. In this case the influence of the phosphorescence on the reading can be neglected shortly after irradiation.