

ENVIRONMENTAL GAMMA RADIATION MONITORING SYSTEM WITH A LARGE VOLUME AIR
IONIZATION CHAMBER

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An improved environmental monitoring system has been designed and tested, consisting of an ionization chamber with 120 l sensitive volume, operated at atmospheric pressure, and a commercial electrometer amplifier with digital voltmeter. The system is controlled by a desk calculator with printer for automated operation and calculation of dose and dose rate. The ionization chamber provides superior dosimetric performance as compared to usual GM-counters and high pressure chambers. The system has been field-tested during the "European Intercomparison Programme for Environmental Monitoring Instruments" organized by the Commission of the European Communities.

Introduction

Up to now air-ionization chambers operated at normal atmospheric pressure have been considered generally unsuitable for low-level-environmental monitoring due to the extremely low ionization currents to be measured. In spite of inferior dosimetric performance and insensitivity to low energy radiation high pressure chambers and GM-counter tubes are most widely used. Due to considerable improvements in electrometer design today commercially available at low cost the application of air ion-chambers for natural background radiation has become a new challenge for dosimetric research. The basic advantage of such chambers is the excellent energy response, linearity over a wide range, uniform directional response and unlimited lifetime combined with reasonable costs.

Ionization chamber

The chamber, shown schematically in Fig. 1 consists of a rugged cylindrical drum made from polyethylene filled with air under normal atmospheric pressure. The nominal volume is 120 l. The wall thickness of 5 mm provides secondary electron equilibrium for photon energies up to several MeV. Due to the low absorption coefficient of polyethylene adequate sensitivity for low energy radiation is obtained. In order to compensate for the wall absorption in the low energy range the inner surface of the chamber is coated with graphite and Al to provide a higher photoelectric yield as compared to air for soft photon radiation. The surface of the compensating layer is connected to the polarizing voltage (normally 300 V) while the outside surface of the chamber is electrically isolated. The collecting electrode consists of a methylmethacrylate tubing with graphite coating. In order to avoid problems with air humidity the chamber is connected to a compensating volume of approx. 10 l in form of a rubber tube.

This way the chamber operates as a normal open chamber which provides the most accurate definition of the effective air mass derived directly from outside atmospheric pressure and temperature and is still sealed against the outside atmosphere. The connecting tube contains a desiccator and activated charcoal filter in order to eliminate the alpha-induced background due to natural radon.

Measuring assembly

The complete measuring system is shown in the schematic diagram Fig. 2. It consists of a high voltage battery (+ 300 V) and a commercial electrometer (Keithley Mod. 602). Either the ionization current or the charge collected at the inner electrode of the chamber can be measured. The output of the electrometer is fed into a digital voltmeter (Hewlett Packard Mod. HP3468A) controlled by a pocket calculator (HP 41CX) with miniaturized printer (HP 82134A) which converts the electrometer output to dose or doserate. The system is fully portable and battery operated and consists of relatively low-cost commercial components. Fig. 3 is a photograph of the complete measuring assembly as used in a field-test.

Dosimetric performance

The dosimetric performance of the system has been evaluated in our dosimetry laboratory at Seibersdorf [1] and in various field-tests during the "European Intercomparison Programme of Environmental Monitoring Instruments" performed under guidance of the Physikalisch-Technische Bundesanstalt, Braunschweig (PTB) for the Commission of the European Communities in 1984 and 1985. The results of the Intercomparison Programme will be published in a CEC document.

Sensitivity and linearity

The determination of the system sensitivity and linearity in the range of 200 nS/h (20 μ R/h) has been performed in a salt mine (Asse II) near Braunschweig at a depth of 775 m below surface. At this test site 5 different reference sources of ^{137}Cs with activities between 0.48 MBq (13 μ Ci) and 8.5 MBq (230 μ Ci) have been used for calibration of the chamber. The doserate of these sources has been determined by the PTB using our low level secondary standard chamber LS-10 of 10 l volume [2]. The sensitivity of the chamber has been in the range of $4 \times 10^{-5} \text{C/R}$ corresponding to 10 fA/(μ R/h). The exact calibration factor for the particular chamber used at the first intercomparison in 1984 was $(93.17 \pm 0.27) \mu\text{R/h.pA}$.

Limit of detection and internal background

These parameters have been determined in Asse II in 1984 and 1985. The natural background level in the salt mine is 1.4 nSv/h (0.14 μ R/h). The internal background of the system has been 8 nSv/h (0.80 μ R/h) with a standard deviation of 0.3 nSv/h (0.03 μ R/h). The limit of detection, defined as 3 sigma of the background reading, is therefore 0.9 nSv/h (0.09 μ R/h). The relatively high internal background is probably caused by traces of some natural alpha-contamination in the chamber material, not by radon.

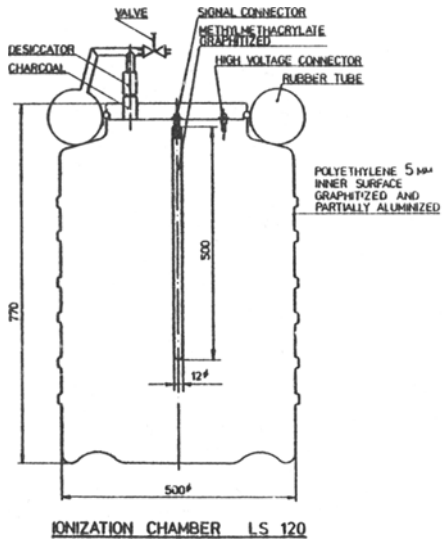


Fig.1. Schematic design of the ionization chamber

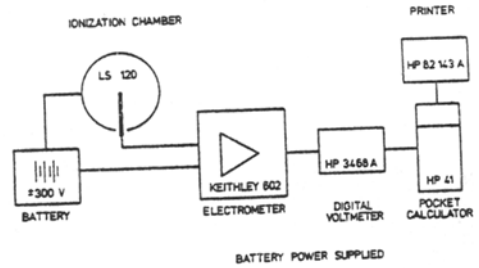


Fig.2. Circuit diagram of the complete measuring assembly



Fig.3. Photograph of the environmental monitoring system as used during a field test

Saturation deficiency and upper limit of range

For the measurement of low-level radiation a polarizing potential of 69 V from a small battery is sufficient. With this high-voltage the saturation loss is below 1 % up to 5 $\mu\text{Sv/h}$ (500 $\mu\text{R/h}$). If the chamber high-voltage is 300 V the range (saturation below 1 %) is extended to 0.1 mSv/h (10 mR/h) and with 1000 V to approx. 1 mSv/h (100 mR/h).

Energy response

The variation of chamber sensitivity for different energies has been studied under free-field conditions in RISØ (1985) and under collimated beam conditions in ASSE II (1985). The final results, evaluated by the PTB and based on our low-level secondary standard chamber LS-10, have not yet been released. In the energy range between 60 keV (^{241}Am) and 1250 keV (^{60}Co) the energy response is approximately $\pm 4\%$.

Directional response

The variation in sensitivity of the chamber around its length axis is negligible. The difference between radiation incidence parallel and perpendicular to the chamber axis for ^{137}Cs radiation is approx. 13 %.

Contribution of cosmic radiation

The cosmic contribution to the natural background has been evaluated on sea in the bay of HELGOLAND near CUXHAVEN (1984) and near RISØ (1985). The gamma radiation background of both ships used for this test has been carefully measured before by PTB and the RISØ laboratory. For our chamber the environmental dose rate by cosmic radiation at sea level is (39 ± 3) nSv/h corresponding to (3.9 ± 0.3) $\mu\text{R/h}$.

Measurement of elevated natural background

A field-test at a site of elevated natural background has been performed in the HARZ-mountains near Braunschweig. After correction for the cosmic contribution and for internal background a natural environmental dose rate of 153 nSv/h (15.3 $\mu\text{R/h}$) has been measured. An official comparison with the values of the other participants has not yet been published.

Conclusion

Practical experience gained during three European Intercomparisons and in long-term tests in our laboratory proved the system described as a useful and accurate device for low-level environmental radiation monitoring. Due to the significant progress in modern electrometer circuitry available at low cost the inherent dosimetric advantages of air-ionization chambers can now be successfully applied for this field of radiation measurement.

References

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2. K.E. Duftschmid and J. Hizo, A Secondary Standard Dosimetry System for Calibration of Radiation Protection Instruments, Acta Physica Academiae Scientiarum Hungaricae, 52 (3-4), p. 275-282, 1982.