A LARGE VOLUME IONIZATION CHAMBER SYSTEM FOR ENVIRONMENTAL MONITORING

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INTRODUCTION

In view of decreasing tolerance levels continuously increasing accuracy requirements for environmental monitoring have forced the development of such equipment to its physical and technological limits. Although ionization chambers inherently provide optimum dosimetric performance, GM-counters are most widely used for this application due to the much simpler electronic circuitry required. Steel-walled high-pressure ionization chambers show a rather poor energy response with distinct low energy cut-off.

In continuation of our long term research and development programme on secondary standard dosimetry systems(1) we designed and tested a large air-equivalent ionization chamber with 120 l sensitive volume, operated at normal atmospheric pressure, which can be used for environmental monitoring. As compared to available high pressure chambers and GM-counter instruments the large chamber provides considerably improved dosimetric performance.

IONIZATION CHAMBER

The ionization chamber consists of a cylindrical barrel made from polyethylene with the outside dimensions 510 mm diameter and 760 mm height. The wall thickness is 5 mm corresponding to an area mass of 0,45 g/cm^2. The walls are coated with graphite on both sides. The wall thickness provides secondary electron equilibrium for photon energies up to several MeV. For compensation of wall absorption losses in the low-energy range the inner wall surface is coated with a thin layer of Al generating a higher photon electric yield as compared to air. For higher energies this compensating layer is transparent. By this method an energy response of $\pm$ 2 % in the range of 30 keV$_{eff}$ and ^{60}Co is achieved. For comparison present GM-counter instruments with energy compensating shields as well as high pressure chambers provide an energy response of about $\pm$ 25 % between 60 keV and ^{60}Co with a complete cut-off below 50 keV.

Due to the cylindrical shape of walls and central electrode the directional response around the circumference is quite uniform. With an effective volume of 120 l the chamber calibration factor is 6,8 kg^{-1} (2,6 . 10^{4}R/C). With a chamber high voltage of 300 V the saturation loss is 10 % at 10 mSv/h (1 R/h). In order to extend the dynamic range to higher doserates with a saturation loss below 1 % at 0,1 Sv/h (10 R/h) the collecting electrode of the chamber is devided into two electrically separated parts deviding the chamber into two sensitive volumes in the ratio 1:100. The chamber is hermetically sealed. Due to the flexibility of the wall material the volume changes according to the outside atmospheric pressure and the internal air mass, which determines the sensitivity, remains constant independent of barometric pressure and air temperature.

Fig. 1 is a photograph of the chamber as used for environmental monitoring in our Research Center.

ELECTRONIC CIRCUITRY

For the measurement of ionization currents in the range of 10 fA up to 100 nA for doserates from 10 nSv/h (1 µR/h) up to 0,1 Sv/h (10 R/h) an electrometer amplifier circuitry with analog/ digital converter is used. In order to cope with a dynamic range over 7 decades two amplifiers are used simultaneously each connected to one part of the collecting electrode. For the amplifier an integrated Varactor-op-amp-modul (Teledyne-Philbrick Mod. 1702) is used which provides a sufficiently low off-set current of 5 fA. The amplifier output is fed into a voltage-to-frequency-converter (BURR BROWN VFC 62) with a resolution of 0,03 % full scale at 100 kHz and a dynamic range of 6 decades. Both amplifiers and the VFC are enclosed in a thermally isolated box containing a Peltier element for temperature stabilization. By changing power supply polarity it can be operated as a cooler or heater and the temperature controlled to ± 5°C. The complete electronic system is located inside the chamber below the top opening and therefore protected against climatic environmental conditions.

The output pulses of the VFC can be directly transmitted through cable or telephon lines or used for telemetric radiotransmission. The pulse frequency is proportional to the doserate. A remote microprocessor circuitry converts pulse frequency into units of dose or doserate and can be used to operate a network of up to 10 chambers simultaneously in a sampling mode.

PERFORMANCE

The ionization chamber has been calibrated by comparison with our low-level secondary standard chamber LS-10[2] with 10 l sensitive volume, which is traceable to the Austrian Primary Standards. The calibration is performed at a doserate in the range of 10 µSv/h with X-ray qualities and gamma radiation according to ISO 4037. In order to test the linearity of doserate measurement down to the limit of detection a series of ^{226}Ra standards of identical geometry and measured activity in the range of 10 µg to 10 mg has been used. The radium standards were positioned free-in-air in 5 m distance from the chamber. The linear-least-square fit of the doserate readings vs. radium weight resulted in an uncertainty of 1 nSv/h in the range of 0,01 - 10 µSv/h.

After calibration of the chamber the limit of detection has been determined be repeated measurements within the shielded enclosure of a whole-body-counter.
Fig. 2 shows a series of 25 consecutive readings measured with an integration time of 1000 s each in the whole-body-counter. With a mean value of 38,3 nSv/h (3,83 µR/h) the standard deviation is 0,77 nSv/h (0,077 µR/h).

The limit of detection, defined as three standard deviations of the background doserate is therefore 2,3 nSv/h (0,23 μR/h). This is comparable to a typical high pressure ionization chamber.

CONCLUSION

The large volume ionization chamber system described is particularly useful for continuous, accurate and remote measurement of environmental radiation around nuclear installations. As compared to instruments presently commercially available it provides considerably improved dosimetric performance. Extended networks can be operated with one central electronic data processing unit and telemetric data transmission is directly possible due to the digital form of information. The dynamic range extends over 7 orders of magnitude which makes the instrument suitable also for application in early warning systems.

REFERENCES

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(2) DUFTSCHMID K.E., HIZO J.: Secondary Standard Ionization Chamber System for Environmental Dosimetry. Proc. 1st Symp. of IMEKO TC 8, Leningrad, (1981).

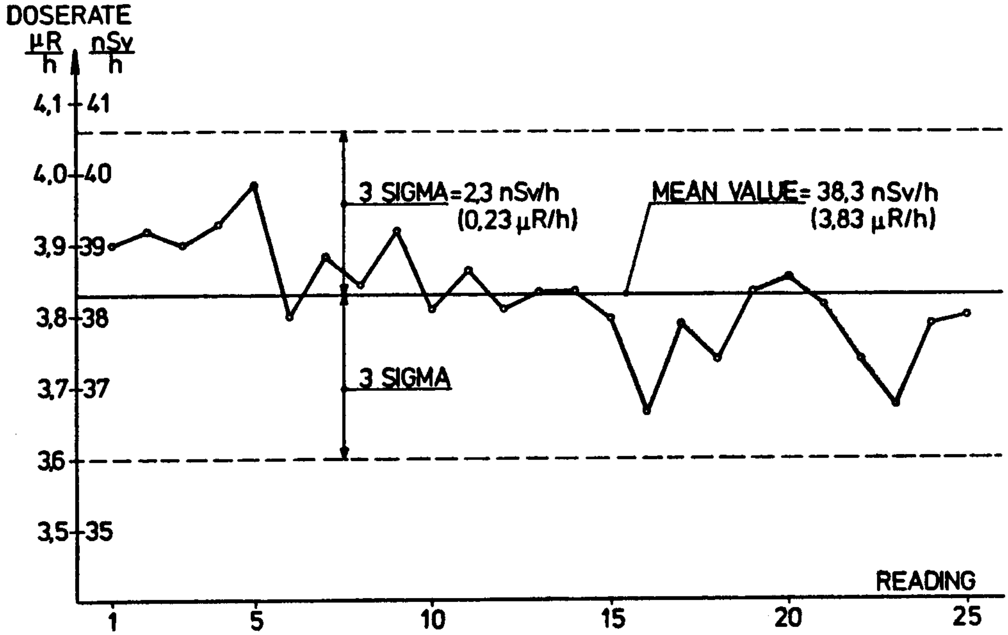

Fig. 2 Environmental Background Doserate measured inside the shielded enclosure of the whole-body-counter

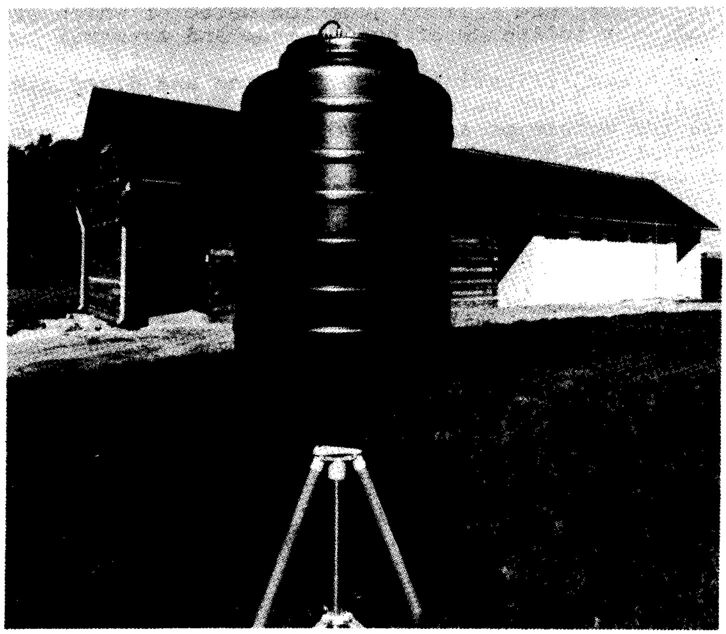

Fig. 1 Photograph of the large volume ionization chamber installed at the Research Center