RADIATION PROTECTION - SELECTED TOPICS
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PORTABLE RADIATION METERS DEVELOPED IN "BORIS KIDRIČ" INSTITUTE

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ABSTRACT

Portable meters designed for X and gamma radiation measurements and beta detection are described. An instrument using ionization chamber is developed with new type of electrometer amplifier. It is designed for precise and reliable exposure and exposure rate measurements. Another instrument with GM counters covers 8 linear ranges: from background up to 10 Sv/h. Some specific solutions and basic measurement characteristics of these instruments are presented.

INTRODUCTION

For over 30 years the "Boris Kidrič" Institute of Nuclear Sciences has been developing the dosimetric instrumentation for the measurements of exposure dose rate, absorbed dose in the air and the tissue equivalent dose. Some of these instruments have been developed for measurements of integrated quantities.

In order to measure the exposure dose rate to a preassigned accuracy in a defined medium it is necessary to use a radiation detector possessing a flat energy characteristic over the entire energy range of measured photons. The problems associated with the flatness of the energy response of a detector become particularly pronounced below 200 keV. The detectors such as GM counters, semiconductor and scintillation detectors are ideal for, e.g., detecting radioactive contamination or for detecting an increased level of radiation, but only in cases where the accuracy of the exposure dose rate measurement is not essential. For the purpose of measuring the exposure dose rate by using these detectors it is necessary to know not only the energy response of the detectors but also the energy distribution of radiation sources. The energy characteristic of an ionization chamber compared to those of other detectors is far flatter, particularly at low energies. For this reason the use of ionization chambers results into far more realistic measurements of the exposure dose rates in comparison to

those obtained with other types of radiation detectors.
Fig.1 shows energy characteristics /1/ of: (a) GM counter-type 1885 and (b) ionization chamber of the Tech.Associates Model "Cutie Pie". The superiority of the ionization chamber is quite clear.

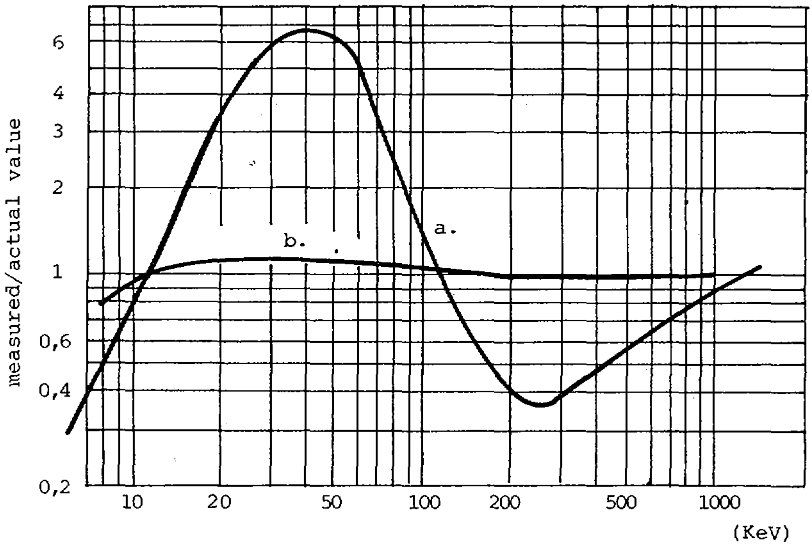

Figure 1. Energy dependences of (a) counter and (b) ionization chamber

The energy characteristics of the semiconductor and scintillation detectors are inferior to that of a GM counter.

Nevertheless the ionization chambers have not been much used in the dosimetric measuring instrumentation. The basic reason for this situation is that at small exposure dose rates ionization chambers produce extremely small dc currents which are difficult to measure even with a very advanced techniques.

This paper describes portable dosimetric instruments for exposure dose and exposure dose rate measurements. Both types of radiation detectors, GM counters and ionization chambers, have been used.

METHODS OF MEASURING EXPOSITION DOSE AND EXPOSITION DOSE RATE

According to the definition the exposure dose rate, as a measure of interaction of ionizing photon radiation and air, is measured by the quantity of separated electric charge per unit time for a defined mass of air. Ionization chamber is the most suitable detector for measuring the above defined quantity. An ideal chamber is air-filled and the electrodes are made of an air-equivalent material thus the absorption by the electrodes is negligible. These conditions are best fulftilled by free air chambers, but, unfortunately they can only be used in specially defined laboratory conditions. In practice one must use chambers which separate the efficient detection mass of air from the environment atmosphere. The chamber walls inevitably absorb some of the measured radiation. If a chamber is not designed of an air-equivalent material, considerable measurement errors could arise.

The measurement accuracy in radiation fields containing gradients is inversely proportional to chamber size. This, together with practical considerations for ease of handling, requires that chambers are made with relatively small volumes ($0.1 \div 1\ dm^3$). The measuring range of these instruments should extend from background level up to radiation fields higher for a factor of 10^{10} /2/. It is quite clear that so wide range can not be covered by one instrument only. The measurements of high exposure dose rates involve additional problems due to recombination process during collection of separated electric charges. This additional problem is mitigated by using small volume chambers, special design of electrodes, and high voltage supplies.

At low exposure dose rate measurements additional problems arise due to residual contents of radionuclides in chamber walls and in the air of the chamber. Measurement of low d.c. currents from an ionization chamber is a problem more or less solvable in laboratory applications. For portable instrumentation for exposure dose rate measurements the temperature range requirements are far more stringent and up to now no optimum sensitivity for this type of instrumentation has been attained.

The design of ionization chambers and electrometer circuits is a long rang activity in the "Boris Kidrič" Institute of Nuclear Sciences. At first the electrometer tubes were used as active input elements of electrometer amplifiers. They have subsequently been replaced by MOS FET transistors. Furher technological improvements made available more reliable JFET transistors. The operational amplifiers, connected as current - voltage converters, are currently used as input circuits of dosemeters, Fig.2. Certain instruments possess measuring ranges for exposure dose measurements, i.e. when the operational amplifier functions as an active integrator, Fig.3.

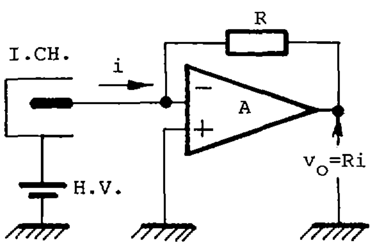

Fig.2. A circuit for measurement of exposure dose rate

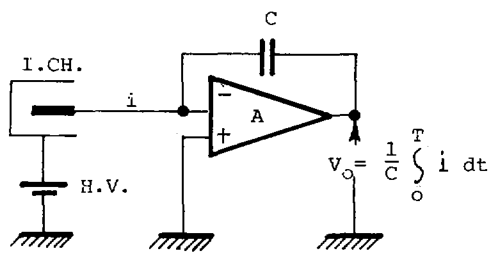

Fig.3. A circuit for measurement of exposure dose

The measuring range of the instrument is varied by varying the feedback element.

The use of GM counters relaxes the problems associated with the design of input electronic circuit of portable exposure dose rate meters. The problems specific for usage of this type of detectors are due to indirect method of measurement of exposure dose i.e. by recording delta electrons generated in photon -gass interactions. Since no amplitudes of these interactions are measured and only their number is recorded the energy dependence is inevitable (Fig.1). Reduction of the energy dependence of GM and similar counters can be achieved through application of special energy shields. At low levels of dose rate the accuracy problems, identical to those met with ionization chambers, are caused by radionuclide content of the counter material. Owing to the pulse character of operation of these counters the measuring range of a detector is limited to three or four decades. Therefore a portable instrument requires the application of at least two detectors. The problem of reliable operation of the instrument is pronounced at high radioation fields. This problem can be solved by special electronic circuits.

The application of semiconductor Si detectors for measurements of exposure dose rates is possible in both dc and pulse operating modes. These instruments exhibit relatively good characteristics at high exposure dose rates, but the obstacle to their wider usage is high cost of the detecting system of a sufficiently good sensitivity and with an acceptable period of measurement /3/.

THE RESULTS

Several types of portable dose meters, with GM counters or ionization chambers, have been developed to the small scale production level.

The first portable exposure dose rate meter, type PD-1, developed in 1959 was based on application of a 1.5 l ionization chamber. The active input element was electrometer tube CK 5886. The measuring range was from 15 mR/h (full scale reading) up to 1.5 R/h /4/.

The following instruments of this type, PD-2 and PD-3, contained as active input elements of electrometer circuits MOS FET transistors whereas all other characteristics were the same as those of PD-1. The specific electronic circuits have been designed for protection of MOS FET transistors in fields exeeding the measuring range of instruments /5/.

The latest instrument, PD-4, uses a 0.6 l ionization chamber and JFET transistor as active input element. This instrument contains a unique electronic system* allowing that the leakage current of the input amplifier, containing FET transistors as active input elements, is more than two orders of magnitude lower from the intrinsic leakage current of the input amplifier. Thus the system offers all improvements implied by JFET transistor application: low offset voltage, low drift of the offset voltage, low current consumption having, at the same time the input leakage current of the order of an MOS FET electrometer amplifier.

The basic diagram showing the principle of operation is given in Fig.4

The compensation current is generated via a high resistance resistor. Temperature dependence of this current is provided by connecting this resistor to a temperature variable voltage source. The experimental evidence showed input leakage currents below $3x10^{-15}$A over a wide temperature range. The warm up time upon switch-on of the amplifier, is considerably shorter than that of a MOS FET amplifier. However, the elapsed time before "0" adjustment of this amplifier is longer than that of a MOS FET amplifier. The effects of "memorizing" input voltage are reduced to minimum.

*Patent application No. 1962/88, Yugoslav Patent Office

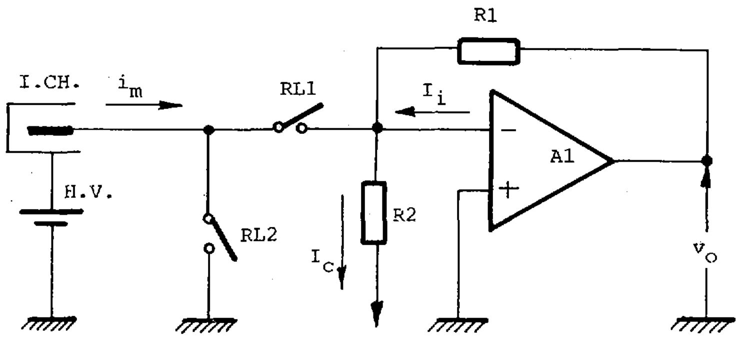

Fig.4. New circuit for measuring extremely low currents

On Fig.4 the following notation is used:

RL1, RL2	- relays of high insulation resistance
A1	- JFET amplifier
R1	- measuring resistor (high resistance)
Ii	- input leakage current of A1
R2	- compensation current feeding resistor (high resistance)

The lowest measuring range for exposure dose rate available with this instrument is 200 pC $kg^{-1}s^{-1}$ and time constant of 2 s. Two measuring ranges for exposure dose, 20 pC kg^{-1} and 200 pC kg^{-1}, are also available.

Several types of portable exposure dose rate meters using GM counters as detectors have also been developed. Currently available are types KOMO-TN and KOMO-TL.

KOMO-TN contains two GM counters (18536 and SI 38 G) and covers the range from background level up to 10 Sv h^{-1}. The detectors are energy compensated and the characteristic of the instrument are of class II (IEC standards). The autonomy of the instrument is more then 100 h.

KOMO-TL has been developed for use in radiation prospection of contaminated surfaces but can also be used for exposure dose rate measurements. High sensitivity of the instrument allows its use in radioecology.

CONCLUSIONS

The portable instrumentation described herewith, offers top performances in exposure dose and exposure dose rate measurements. The sensitivity of this instrumentation ranges from background level up to the highest levels of exposure dose rates in practical applications. Technical design and applied technology warrant high reliability /8/.

REFERENCES

1. Bellian, J.G., Limitations of helth physics instrumentation, Victoreen Instruments Div., Report 8027A, 1972.
2. Šobajić, V.M., Damljanović, D.D., Koturović, M.A., Šmelcerović, A.M., Drndarević, R.V., Development of the electronic radiation protection instruments at the Boris Kidrič Institute - Vinča, Proceedings of the XIV Regional Congress of IRPA, Yugoslav-Austrian-Hungarian Radiation Protection Meeting, Dubrovnik, 1988, pp.413-416.
3. Drndarević, R.V., A Low-noise, very low-power charge-sensitive amplifier suitable for portable spectrometers with semiconductor detectors, Proceedings of the 27th Yugoslav Conference of ETAN, Struga, 1983, Vol 2, pp. 101-108.
4. Šobajić, V.M., A portable radiation monitor, IVth Symposium ETAN, Zagreb 1959, pp. 451-453.
5. Šobajić. V.M.. Danilović, Z.D.. A circuit for protection of insulated gate field-effect transistors in dc low current amplifiers, Isotopenpraxis, 1975, V.11, No.3, pp.99-102 (in Serbocroation).
6. Šmelcerović, A.M., Koturović, M.A., Djurić, G., Petrović B., Measurements of radioactive polutions of plants product, Proceedings of the first Yugoslav consultation "Protection and rescue of plants and plants product from RHB contamination", Dubrovnik, 1987, pp.309-317 (in Serbocroation).