A SPHERICAL GRAPHITE IONIZATION CHAMBER

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ABSTRACT

This paper describes an exposure ratemeter made of graphite ion chamber. The sensitive volume is 14 cm^3. The wall is 5 mm in thickness. The DC amplifier with a high input impedance consists of several stage differential amplifications, and is used for measurement of the ionization currents. Six ranges are able to cover a wide range of exposure rates. The full scale of the maximum range is 75 C/(kg · h). The lowest measurable limit is 5 mC/(kg · h). The zero drift within 8 h is less than 5% of each full scale. This instrument provides with a relatively convenient method for the measurement. The main advantages of the ionization chamber over other methods lie in rapidity and accuracy, and the change in radiation field with time can be indicated directly. It is particularly successful in acting as a routine dosimeter under high exposure rates.

Keywords: High dose Exposure ratemeter Gamma dose Spherical ionization chamber Cavity ionization chamber

1 INTRODUCTION

The applications of intensive radiation field are increasing, hence its measurement is very important. We developed two kinds of cavity ionization chambers in the past. One is a cylindrical graphite cavity ionization chamber[1], and the other is a plane-parallel extrapolation chamber[2]. They have been successfully used for the calibrations of radiation sources and field instruments, but are not satisfied for measurement in situ, especially in an intensive radiation field adopted commonly. In order to overcome all of the difficulties, considering various problems related to intensive fields, such as conductivity induced, the collecting of ions and so on, we have developed an exposure ratemeter for monitoring in process of radioisotope production. It is also suitable for industrial radiation processing, non-destructive inspection, *etc*.

As it is now well known, the radiation effect depends on absorbed dose in material interested[3]. For gamma radiation, if exposure rates ($\dot{X}$) have been determined, the absorbed dose rate ($\dot{D}$) in any material irradiated can be obtained by some conversion factors[4] which are used to transfer the numerical value of exposure to that of absorbed dose in the medium irradiated. The absorbed dose rate $\dot{D}$(Gy/h) in material (atomic number Z) irradiated under the conditions of electron equilibrium is given by

$$\dot{D}=2.5\times10^{-6}\times\dot{X}(\mu_{en}/\rho)_z/(\mu_{en}/\rho)_a$$

Here, the $\dot{X}$ is exposure rate in C/(kg · h), the $(\mu_{en}/\rho)_z$ and $(\mu_{en}/\rho)_a$ are mass energy absorption coefficients of material irradiated and of air respectively ($W=33.85$ eV).

2 GENERAL ASPECTS OF THE INSTRUMENT

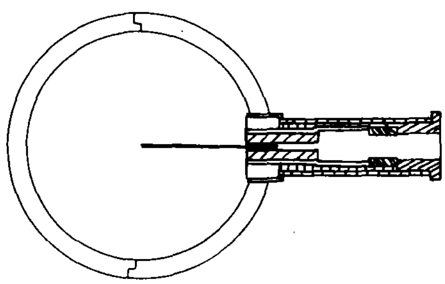

Fig.1 Construction of the spherical graphite ion chamber and connector

At present, gamma radiations from cobalt-60, radium-226 and caesium-137 sources are used extensively. Therefore the energy range of measurement from 0.3 to 3 MeV have been determined. In order to minimize the disturbance of radiation field resulted from insertion of ionization chamber and obtain a good independence of direction, the chamber must be made as small and isotropic as practically possible.

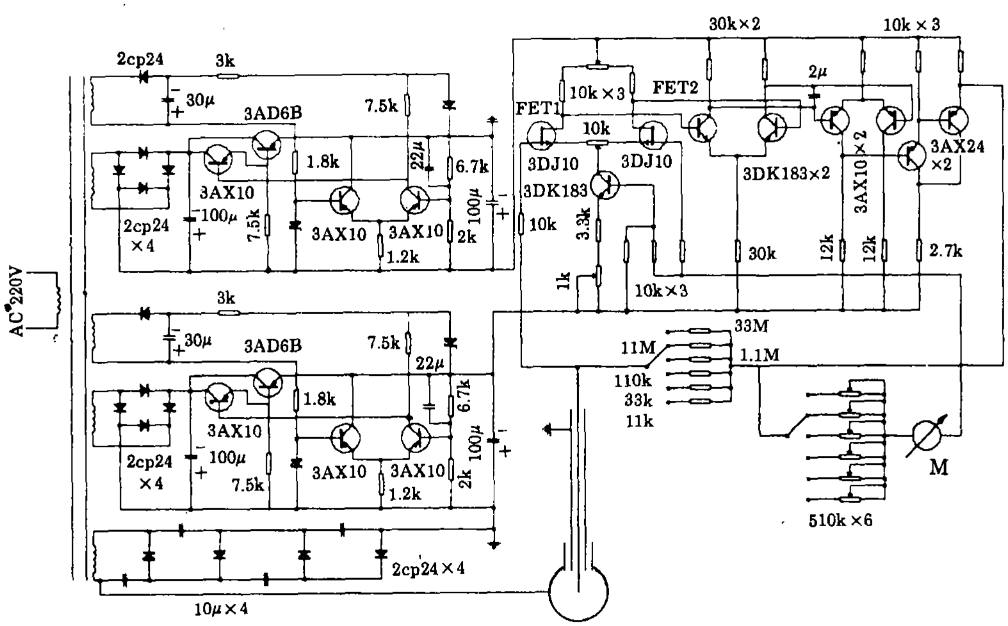

Fig.2 Electrocircuit of the DC amplifier with high— input impedance and power supplies

Hance, the detector of a small spherical ion chamber with a diameter of 3 mm has been designed (see Fig.1). The spherical outer case is made from two halves and then attached together. The wall and central electrode both are made of graphite with a high purity (reactor-grade). The thickness is 5 mm. The collecting electrode and guard ring are separated by Teflon with a good insulation properties in a wide range of temperature and surface leakage-resisting due to humidity. It was experimently shown that the results measured were unchanged at ambient temperature up to 100 °C.

The DC amplifier (see Fig.2) with high input impedance is composed of several stage amplifications for measurement of the ionization current from the ionization chamber. A pair of junction-type field effect transistors (3 DJ 10 type) with identical parameters obtained by careful selecting are used for the input stage. By means of careful adjustment the working orders with zero temperature coefficient have no drifting with temperature. Using direct couping between the stages and the voltage gains are very high.

3 SOME MAIN PROBLEMS NEED TO BE CONSIDERED UNDER INTENSIVE RADIATION FIELDS

Some new problems have been considered as regards the measurement of high ionization rates by means of the ionization chamber. These major factors must be considered in intensive field are as follows:

a. The currents induced during irradiation will cause a reduction of resistivity within insulating materials temporarily. It is experimentally shown that the conductivity induced depends directly on the applied voltage, dose rate, irradiation time and temperature during irradiation[5-7]. Since the reduction of resistivity occurs during irradiation, while its recovery is gradual with a time constant of the order of several hours or days after radiation, so that the ionization chamber requires a rest period before it will be used again. A good insulating material (Teflon) was used for the instrument. The insulating material of a long cable (STY-VP 4 type) is polyethylene. They have good properties of specific resistance.

b. Unlike measurement of low dose-rate, in order to prevent the electronic components from direct exposure to a high radiation field and to reduce the extraneous currents, the ionization chamber was linked with the DC amplifier through a double-concentric cable (STY-VP4 type) of 20 m length. The central conductor in the cable was connected to the collecting electrode. The inner braided conductor was then connected to the guard ring which always retains at the ground potential, but the outer braided conductor was connected to the high-voltage electrode. The HV is applied to it. The sections irradiated therefore must be minimized as practical as possible.

c. In common range [0.3C/(kg.h)] the ion collecting coefficients may reach over 99%. Lack of saturation for the ion collection will result in two sources of errors at very high ion rates.[9] One is a under estimation of the measured values, and the other is a poor of energy dependance. At high ionization rates the theoretical formula by Boag[8] has been adopted in order to determine the correction factors of collecting efficiency.

4 CALIBRATIONS

The instrument has been calibrated by a silver- activated phosphate glass dosimeter and a Baldwin- Farmmer dosimeter in a known radiation field of cobalt- 60 source facility with 1.85 PBq. There is a good agreement with the difference of 3% between the results from the two calibration methods.

5 SUMMARY

This instrument is developed on the basis of the cavity ionization theory and the definition of exposure. As the detector is a small spherical shell, the response is independent of incident directions and energy of gamma rays. Using the correction factors of the collecting coefficients this instrument may be used to measure a higher exposure rates up to 75 C/(kg · h). It has a maximum output of −5 V and can be connected with an automatic recording system. The instrument has been successfully used during and after reconstruction of a heavy- water research reactor. It also has been used to monitoring in production of radioisotopes for many years.

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