PERFORMANCE OF ELECTRET IONIZATION CHAMBERS IN MAGNETIC FIELD

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***Abstract*—Electret ionization chambers are widely used for measuring radon and radiation. The radiation measured includes alpha, beta, and gamma radiation. These detectors do not have any electronics and as such can be introduced into magnetic field regions. It is of interest to study the effect of magnetic fields on the performance of these detectors. Relative responses are measured with and without magnetic fields present. Quantitative responses are measured as the magnetic field is varied from 8 kA/m to 716 kA/m (100 to 9,000 gauss). No significant effect is observed for measuring alpha radiation and gamma radiation. However, a significant systematic effect is observed while measuring beta radiation from a ^{90}Sr-Y source. Depending upon the field orientation, the relative response increased from 1.0 to 2.7 (vertical position) and decreased from 1.0 to 0.60 (horizontal position). This is explained as due to the setting up of a circular motion for the electrons by the magnetic field, which may increase or decrease the path length in air depending upon the experimental configuration. It is concluded that these ionization chambers can be used for measuring alpha (and hence radon) and gamma radiation in the range of magnetic fields studied. However, caution must be exercised if measuring beta radiation.**

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Key words: electrets; magnetic fields; radiation, alpha; radiation, beta

INTRODUCTION

ELECTRET ION chambers (EIC) are integrating ionization chambers (Kotrappa and Stieff 1993). An electret (electrically charged Teflon) serves both as a source of electric field and as a sensor. The electret is located at the bottom of the chamber, which is made of electrically conducting plastic. Radiation entering the chamber causes ionization in the air volume, and the ions produced inside the air volume are collected by the electret. The change in charge is measured using a portable charge reader and is the measure of the integrated ionization over the sampling period. These chambers are widely used for measuring radon in air (Kotrappa et al. 1990) and environmental gamma radiation (Fjeld et al. 1994; Hobbs et al. 1996). These chambers are also used for measuring alpha and beta contamination levels (Kasper 1999; Kotrappa et al. 1995). One feature of these detectors, which makes them unique, is that there are no electronic components or power supply associated with the detectors. Because of this property, these detectors can be used in areas with magnetic fields present without any worry about affecting the electronics. There may be situations when radon or radiation measurements need to be performed in the vicinity of significant magnetic fields, such as in the vicinity of accelerators. Consequently, it is of interest to examine the effects of magnetic field on the performance of these ionization chambers.

MATERIALS AND METHODS

The Magnetic Materials Group of the NIST (National Institute of Standards and Technology) has a suitable large 25.4-cm-pole-diameter electromagnet whose magnetic field can be controlled between 0 and 716 kA/m (0 to 9,000 gauss) (GMW Magnet Systems, Model 3474-140 Electromagnet, P.O. Box 2578, Redwood City, CA 94064). In addition, the gap between the pole pieces is large enough to introduce the detectors. The electret ion chamber chosen for the tests was a circular chamber 8 cm diameter and 3 cm high. The electret is screwed into the chamber from the top. Such EICs are used for measuring alpha, beta, and gamma radiation (Fjeld et al. 1994; Hobbs et al. 1996; Kasper 1999; Kotrappa et al. 1995). Alpha or beta sources are incorporated inside the chamber to serve as a radiation source. Gamma radiation is beamed over the detector while in the magnetic field.

Fig. 1 shows a schematic of the experimental arrangement. The detector can be exposed either in the horizontal mode (i.e., with the radiation propagation

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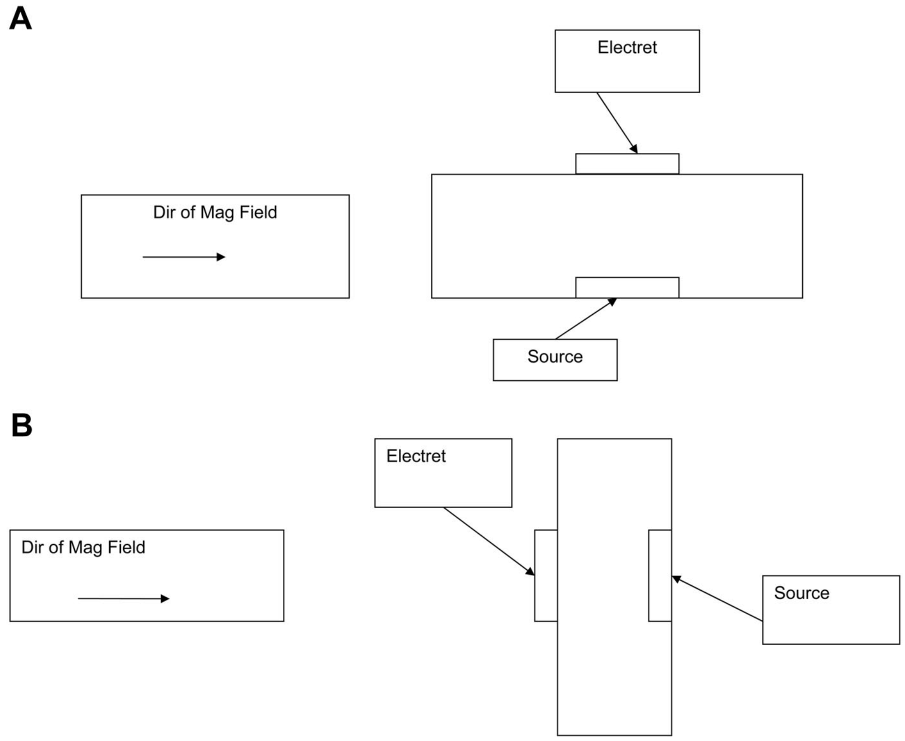

Fig. 1. (a) Schematic of horizontal arrangement of the EIC. The source is alpha or beta. Arrow shows the direction of magnetic field; (b) Schematic of vertical arrangement of the EIC. The source is alpha or beta. Arrow shows the direction of magnetic field.

being in the same horizontal direction as the magnetic field) or in the vertical mode (i.e., with the radiation propagation direction being perpendicular to the magnetic field direction). Fig. 1a shows the horizontal mode and Fig. 1b shows the vertical mode. ^{230}Th with an activity of 250 Bq was used as the test alpha source. ^{90}Sr-Y with an activity of 4.17 kBq was used as a test beta source. The gamma radiation from a ^{60}Co source is directed through the magnetic field area. The gamma radiation level was about 0.3 mGy h^{-1} at the location of the detector.

Since the object of this experiment is to determine the response with and without the presence of a magnetic field, relative responses need to be measured and compared. The response of the EIC is defined as the change in charge of the electret per unit time. This is an index of rate of radiation exposure. A statistically significant measurable change in surface voltage (40 to 50 volts) on the electret is obtained by measuring the alpha source for 10 min, the beta source for 30 min, and the gamma source for 30 min. The magnetic field is directed toward the detector. In separate experiments, the detectors are positioned in horizontal and vertical positions to determine the orientation effect of the magnetic field, if any. Any effect is determined by taking the ratio of the response of the EIC to that of the response in zero magnetic fields.

RESULTS

Effect of magnetic field on the measurement of alpha radiation

There was no measurable effect of magnetic field on the measured alpha radiation in any detector orientation for magnetic fields up to 716 kA/m (9,000 gauss).

Effect of magnetic field on the measurement of beta radiation

Significant effects are observed. See Table 1 and Fig. 2. The detector response increased from 1.0 to 2.5 while the detector was positioned in the vertical orientation. The detector response decreased from 1.0 to 0.65 while the detector was in the horizontal position.

Table 1. Relative response of EIC in magnetic fields. Response with no magnetic field is taken as 1.0.

Magnetic field in kA/m (gauss)	Vertical orientation	Horizontal orientation
0	1.00	1.00
7.9 (100)	1.05	0.98
39.8 (500)	1.20	0.97
79.6 (1000)	1.35	0.95
159 (2000)	1.60	0.90
318 (4000)	2.00	0.81
557 (7000)	2.50	0.63
716 (9000)	2.70	0.60

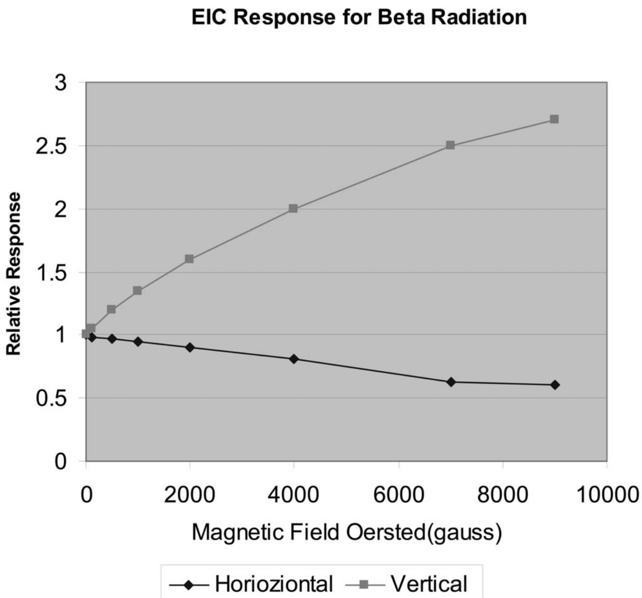

Fig. 2. Relative response of the EIC for measuring beta radiation from ^{90}Sr-Y for horizontal and vertical configurations.

Effect of magnetic field on the measurement of gamma radiation

^{60}Co radiation (exposure rate about 0.3 mGy h^{-1}) is directed into the magnetic field area perpendicular to the direction of the horizontal field maintained at 716 kA/m (9,000 Oersted). With the EIC being located between the poles of the magnet, no significant effect is observed in either the vertical or horizontal orientation of the detector.

DISCUSSION

There is no change in responses for alpha sources with and without a magnetic field present. This is not unexpected because this magnetic field is not sufficient to affect the path of the alpha particles. Therefore, while measuring alpha sources or radon in air, magnetic fields up to 716 kA/m (9,000 gauss) do not interfere with the measurements.

There is, however, a significant change in the responses for beta radiation detectors when in the presence of a magnetic field. The magnetic field sets the electrons (beta radiation) into circular motion. Such moving electrons can spend more or less time in the air depending upon the axis of the circular motion, which depends on the direction of the magnetic field and the direction of radiation propagation. Increased time in the air results in more ionization while less airtime means decreased ionization. For example, in the vertical orientation, electrons set into a circular motion by a horizontal field will have longer path lengths, resulting in more ionization and a higher detector response. On the other hand, in the horizontal mode, the electrons set into circular motion will meet the depositing surfaces quicker and will have shorter path lengths, resulting in less ionization and a lower detector response. This model explains the effects found in the present experiments. In addition, the magnitude of the effect increases with the magnetic field strength.

There is no observable effect on the response for gamma radiation detection, both in the vertical and horizontal detector orientations. This is a surprising observation. In ionization chambers, the ionization is caused by the secondary electrons emitted from the surface of the wall. Mean initial energy of the electron emitted from the plastic surface for ^{60}Co gamma rays is expected to be about 0.45 MeV (Shani 1991). Since a significant effect for the beta radiation is observed from ^{90}Sr-Y, some effect is expected. The reasons for observing no significant effect are not clear. The differences in the electron energies may be the reason.

CONCLUSION

EIC detectors can be used for measuring alpha and gamma radiation in magnetic fields, whereas these detectors may give either lower or higher responses while measuring beta radiation exposures. Handheld ionization-based instruments could not be used in the magnetic field because of the possible effects of strong magnetic fields on the electronics of the devices. Units such as the EIC, which do not have incorporated electronic circuits, are not affected by magnetic fields when used for measuring gamma radiation. When magnetic fields are encountered, such as in accelerators, gamma radiation surveys can be successfully made using EIC-based instruments. However, the EIC does not give true responses in the presence of magnetic fields while being used to measure beta radiation. Because of a systematic variation in detector output with magnetic field strength, a correction factor can be derived, specific to the beta-emitter isotope. The most important application of EIC is in measuring radon in air. Since radon is an alpha emitter, these EIC detectors are usable in magnetic fields.

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