SOME APPLICATIONS FOR SEMICONDUCTOR DETECTORS IN HEALTH PHYSICS

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Abstract—Continuing earlier detector development, a small group in the Health Physics Department started work in the semiconductor detectors field in 1963, with a feeling that these might be valuable for spectrometry as well as low level counting. The present paper will deal with germanium detectors, which is produced in sizes up to 9 cm³ at the time of writing (March '66).

An attempt to make a well-type detector is to be done presently and results will be reported.

Some of our detectors are in use in health physics applications, such as fallout measurements (^{57}Co, ^{155}Eu, ^{134}Cs, etc.), identification of components of contaminations and tracer techniques in studies of filter efficiencies. Some examples will be reviewed in the paper.

1. INTRODUCTION

During the last 10 years a small group in the Health Physics Department at Risö Research Establishment has been working on the development of different types of detectors such as low level geiger counters and proportional counters for contamination monitors, etc. [1] As a natural continuation a development program of semiconductor detectors was started some 3 years ago. This work was originally concentrated on silicon detectors in order to investigate their low level characteristics.

The interest, however, shifted to the germanium detectors due to their high resolution capabilities. A number of detectors of different sizes has been produced and some of them used in routine work in the department. After a survey of the more important characteristics of some detectors examples of their use in practical work will be given.

2. Ge(Li) DETECTOR SYSTEMS

For the production of semiconductor detectors of large active volume the method of lithium drifting is used. [2] Typical shapes of detectors are the flat, parallel type having a certain area and sensitive depth, and the so called coaxial type (Fig. 1). The sensitive volume of the flat detector is restricted to 10–12 cm³ at present while the coaxial type is produced up to 53 cm³. [3] A typical size will be 10–30 cm³. Also shown in Fig. 1 is a coaxial type with a drilled hole for use as a "well-type" detector. All types have been produced at our laboratory, the last mentioned only in a single case with not quite satisfactory compensated thickness,

Table 1.

Type	Volume	Size	Sensitive depth	Low energy resolution	Min. distance for source
Flat	2·2 cm³	4·4 cm²	0·5 cm	3·0 keV	0·6 cm
Coaxial	9 cm³	2·3 cm diam.	0·8 cm	2·4 keV	1·6 cm
Well, 16 mm	6 cm³	2·5 cm high	0·4 cm	5·1 keV	0·2 cm

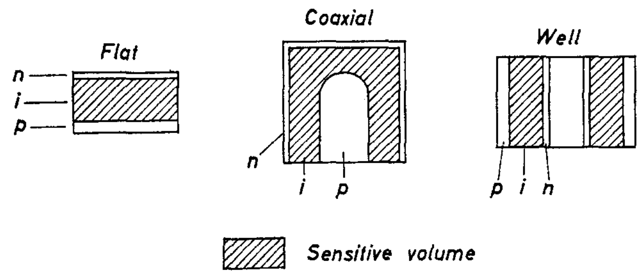

FIG. 1. Types of Ge(Li) detectors.

while the other types have specifications comparable with values from the literature.

Table 1 gives data for the detectors used.

The detectors are mounted, as shown in Fig. 2, in a vacuum chamber on a support cooled by liquid nitrogen through a cold finger.

The amount of nitrogen used is about 1 litre per day. Electrical connection is made to a low noise amplifier system and a 256 channel analyser, this number of channels actually being too low.

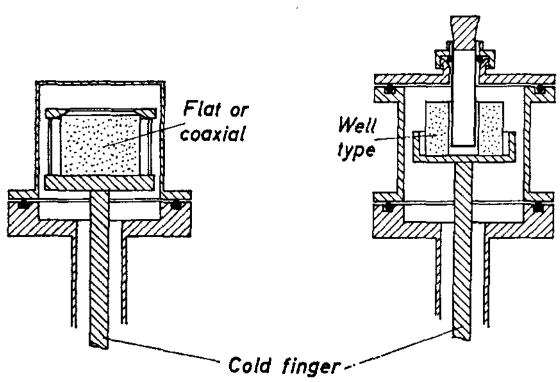

FIG. 2. Mounting of detectors.

A series of calibration measurements was made using a set of standard sources from the IAEA in Vienna. Results are shown in Fig. 3, where the source to detector surface distance was 10 cm. The results for 3 × 3 in. NaI(Tl) crystal is plotted for comparison. At 1 MeV the total number of counts in the photopeak is around 50 times higher in the scintillation detector, but taking into account the much better resolution for the Ge-detector, the height of the peak above a continuous background will be within a factor of 2 as shown by the dotted line. Figure 4 shows results of calibration

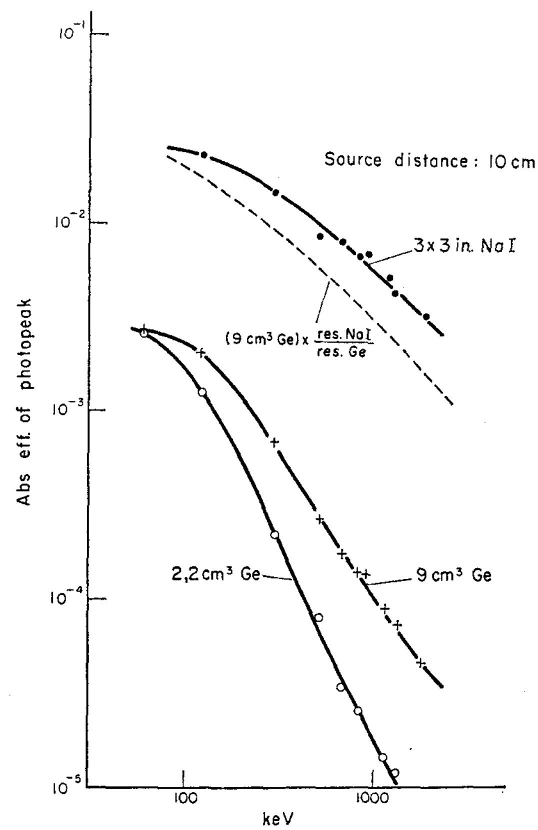

FIG. 3. Efficiency curves for 10 cm source distance.

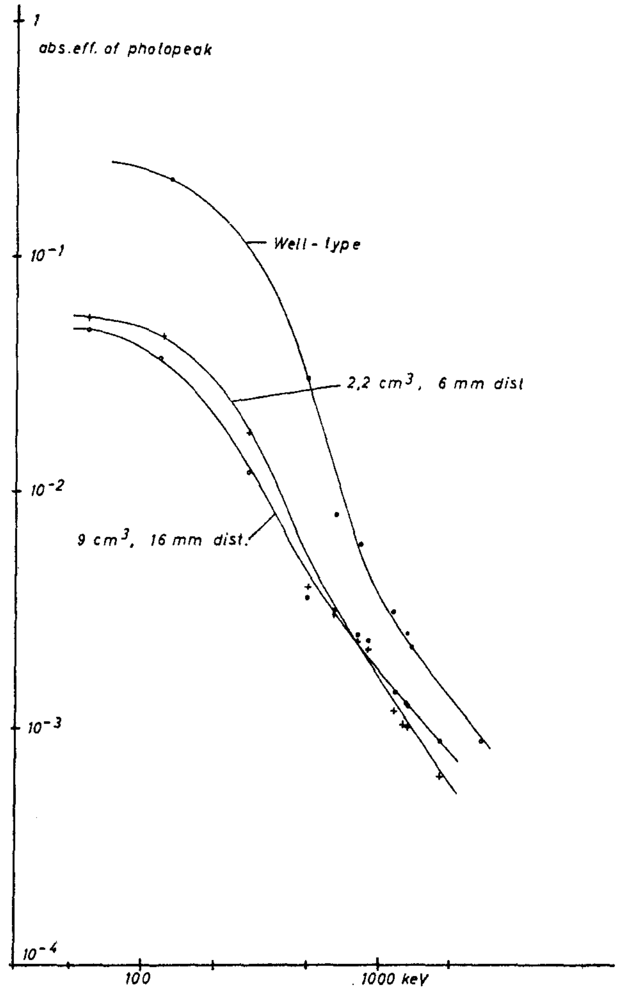

FIG. 4. Efficiency curves for close geometry.

with the sources in close geometry, which for the 9 cm^3 crystal should have been closer through a better mounting. Also shown is a curve for the well-type detector using samples of 0·5 ml. It is our hope to construct a similar detector with a thicker sensitive layer and a somewhat better resolution, giving a better high energy performance.

3. LOW LEVEL COUNTING

For this purpose the 2·2 cm^3 detector has been used for more than a year. The detector is operated in anticoincidence with a 4 × 3 in. well type NaI(Tl) crystal (see Fig. 5).[4] A ^{137}Cs spectrum obtained with this system is shown in Fig. 6. It is seen that the high energy part of the compton distribution is much reduced and the sharp edge removed giving an advantage in analyzing complicated spectra. The system also gives some reduction of the background due to external sources. Figure 7 gives an example of this type of measurements. The amount of ^{137}Cs in the sample is approximately 25 nCi.

Figure 8 gives a similar example for the 9 cm^3 detector. An old air filter sample is measured with this detector and the 3 × 3 in. NaI(Tl)

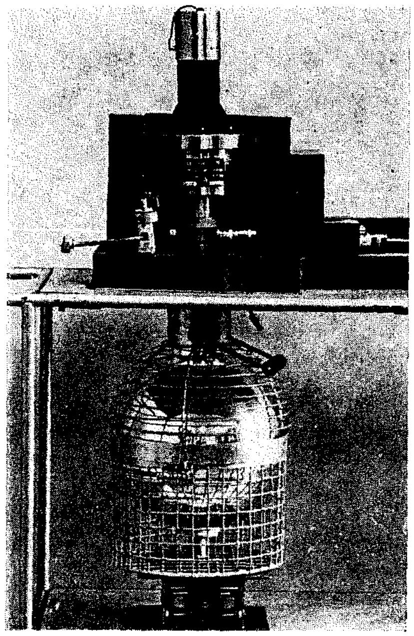

FIG. 5. Detector with anticoincidence system.

detector. It is seen that the following isotopes ^{54}Mn, ^{65}Zn, ^{106}Rh, ^{125}Sb, ^{137}Cs, ^{144}Ce, ^{155}Eu are clearly resolved in the germanium system whereas the ^{57}Co and ^{155}Eu cannot be distinguished from the ^{144}Ce in the scintillation spectrum.

Figure 9 shows a spectrum with the lines of ^{134}Cs and ^{137}Cs measured with the well-type detector. The intention is to use ^{134}Cs as a tracer during a radiochemical treatment of samples in order to concentrate small amounts of ^{137}Cs activity.

Table 2 gives estimated detection limits assuming counting time of 1000 min for samples containing only a single isotope and an accuracy of $\pm$ 20%.

For a NaI(Tl) detector the ^{137}Cs detection limit using the same definition is 5–10 pCi.[1] The figures for the well-type will probably be improved in the future.

4. IDENTIFICATION OF CONTAMINATION

Due to the high energy resolution of the germanium detector, it is an obvious choice for identification purposes. Figure 10 shows a spectrum of a part of a reactor cooling system containing the following activition products: ^{51}Cr, ^{58}Co, ^{59}Fe, ^{60}Co. Experience with this type of measurements shows that the components of mixed radioactivity may be determined faster and more positively than previously.

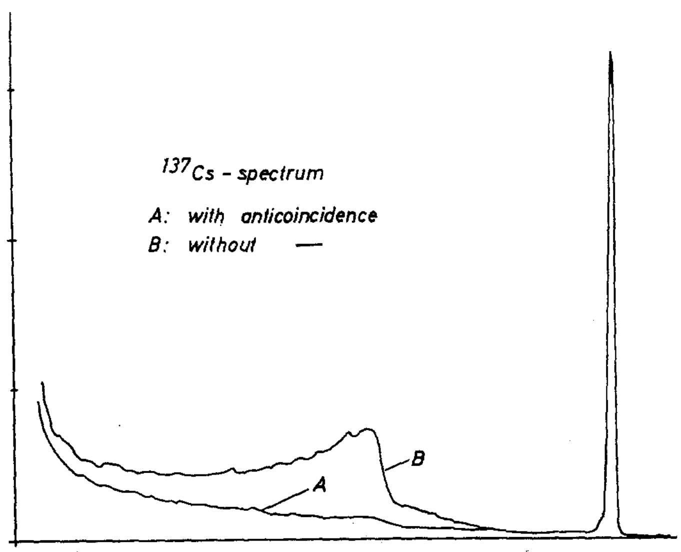

FIG. 6. Spectra with and without anti-coincidence.

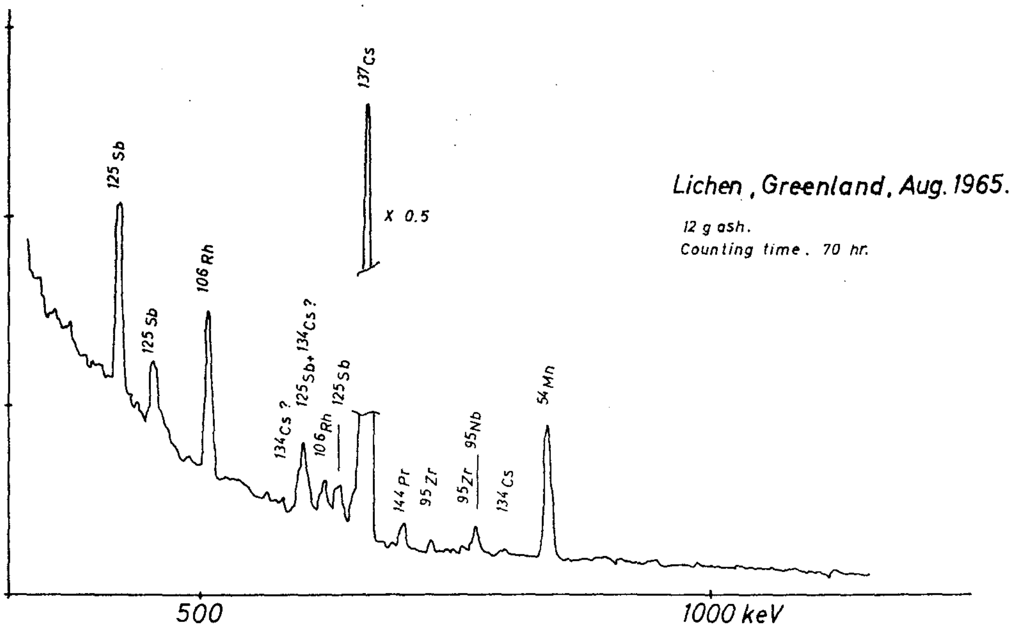

FIG. 7. Sample measured with the anti-coincidence system.

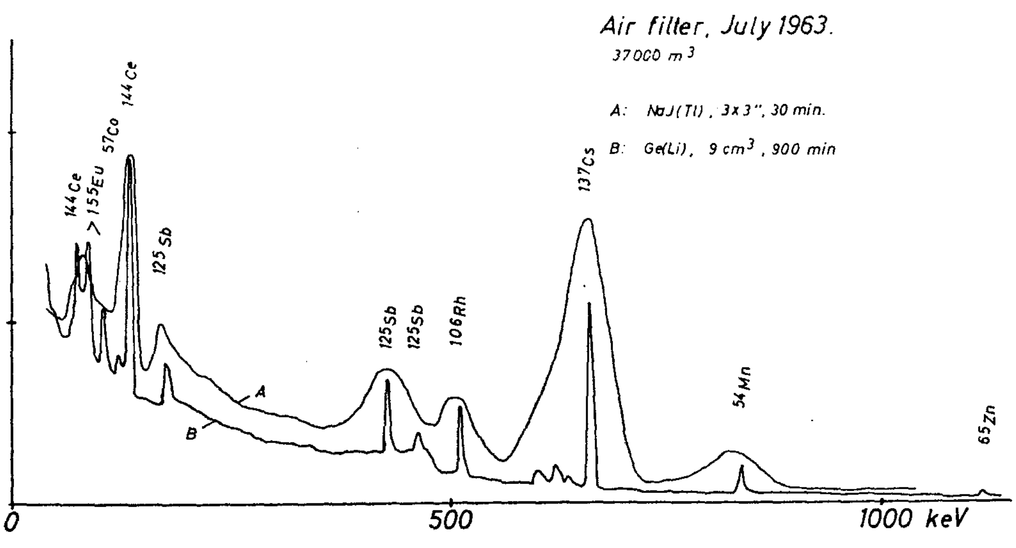

FIG. 8. Sample measured with the 9 cm³ detector.

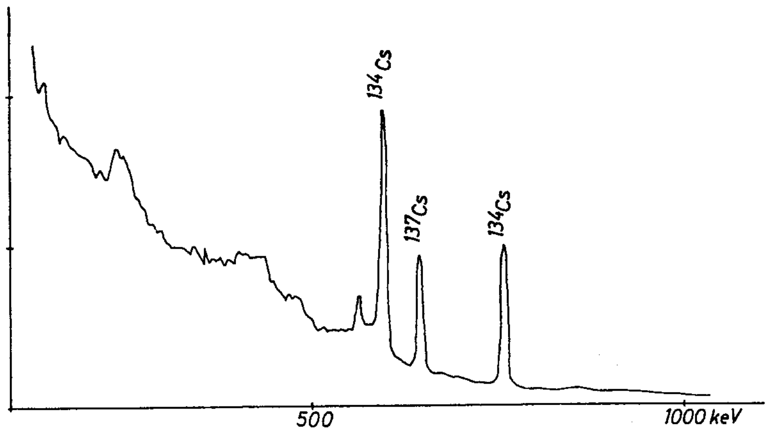

FIG. 9. Well-type detector, ^{134}Cs, ^{137}Cs spectrum.

Table 2. Minimum Detectable Activity

Detector	^{57}Co	^{137}Cs	^{60}Co
2·2 cm^3	1–2 pCi	10 pCi	15–20 pCi
Well	10 pCi	10–15 pCi	15–20 pCi

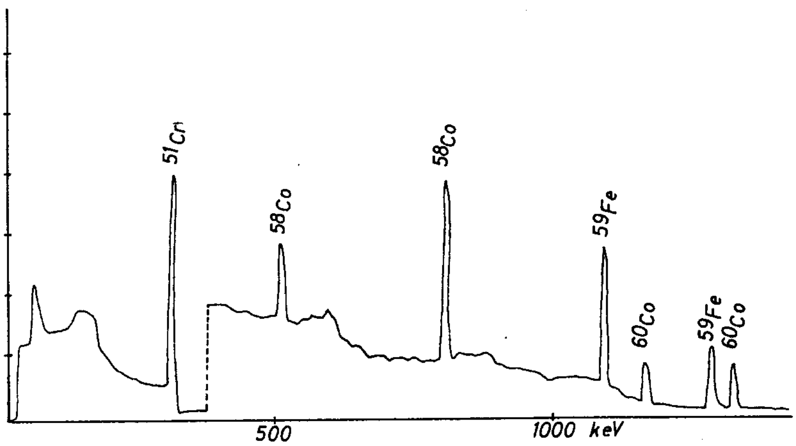

FIG. 10. Activation products from reactor cooling system.

5. CONCLUSION

As shown in the examples given, the use of germanium semiconductor detectors is favoured for most types of measurements involving gamma spectrometry. It is the opinion of the author that it should also be recommended in the field of health physics.

6. ACKNOWLEDGEMENT

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