

Title:

SKIN DOSE MEASUREMENT WITH MICROSPEC-2™

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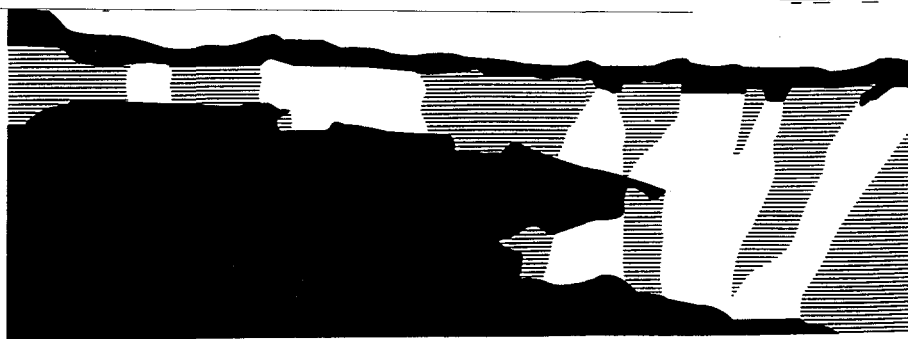
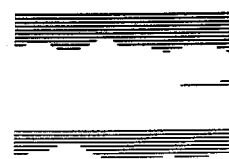
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# SKIN DOSE MEASUREMENT WITH MICROSPEC-2™

## Part I. experimental measurements

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### ABSTRACT

For many years, the Eberline HP-260™ beta detectors were used for skin dose measurements at Los Alamos National Laboratory. This detector does not measure the beta spectrum and the skin dose can only be determined if the contaminating radioactive isotope is known. A new product MICROSPEC-2™, has been developed which consists of a small portable computer with a multichannel analyzer and a beta probe consisting of a phoswich detector. The system measures the beta spectrum and automatically folds in the beta fluence-to-dose conversion function to yield the skin dose.

### INTRODUCTION

Skin contamination with radioactive materials is not a frequent problem at Los Alamos National Laboratory, however to determine skin dose accurately is not a simple task. For many years, we used Eberline HP-260™ beta detector to measure beta activity. HP-260 consists a thin window GM counter. Its detector efficiency depends on beta energy. A proper correction has to be made for radiation strength. If we know the contaminating radioactive isotope, we can assess beta dose from a published table such as the one by Cross et al<sup>(1)</sup>. In practical operation, we used a table, where skin dose was calculated in terms of HP-260 measured counts for many radioactive isotopes frequent detected in our working places <sup>(2)</sup>.

A new product MICROSPEC-2™ has been developed by Bubble Technology Industries (BTI)<sup>(3)</sup>. The system measures the beta spectrum and then automatically

folds in the beta fluence-to-dose function<sup>(4)</sup> to calculate the skin dose. In this paper we will present the results of dose measurements with three standard sources and compare the results with Monte-Carlo simulations using ITS<sup>(5)</sup>.

Two corrections should be considered for any skin dose measuring instrument: (1) the reduction in detection efficiency for low energy beta particles due to the absorption in the detector window and (2) the increase in counts due to back scattering of electrons from tissue. These corrections have been incorporated in the current analysis software for MICROSPECT-2 B-probe.

### **THE MICROSPEC-2™**

The BTI MICROSPEC-2™ is a portable spectroscopic survey system with the possibility of isotope identification. It can be equipped with four different probes for different kinds of measurement purposes. E-Probe is used for environmental survey of gamma rays, G-Probe is designed for high field gamma-rays, X-Probe is developed for measurements with x-rays, and B-Probe is then specially for beta-ray detection.

The B-Probe consists of a 32 mm diameter phoswich detector comprised of a pair of scintillators. The front scintillator is a thin section of CaF<sub>2</sub> and the second detector is a plastic scintillator. The thinness of the CaF<sub>2</sub> scintillator minimizes the likelihood of gamma rays depositing energy in the scintillator and increases the probability that an incident beta particle will traverse the scintillator and enter the plastic scintillator before stopping. Events in the two scintillators can be distinguished electronically on the basis of their different pulse shapes. In order for the probe to register an event as a beta particle, light output must be observed from both scintillators simultaneously. If the detectors are not in coincidence then the event is discarded. The phoswich probe produces an output signal which is directly proportional to the energy of the incident beta particle.

From the viewpoint of external radiation protection, the minimum beta particle energy, which will contribute to skin dose, is 60 keV. Beta particles below 60 keV cannot penetrate the outer layers of the skin to pose a biological hazard. Due to the protection offered by attenuation in air and clothing, most beta particles less than a few hundred keV are not of great concern to health physicists. The spectroscopic operating range of MICROSPEC-2™ is designed from 100 keV to above 3 MeV. Unlike conventional survey/dose meters where elaborate corrections must be made

to insure some kind of flat energy response, the MICROSPEC-2<sup>TM</sup> gives accurate dose measurement over the whole energy range because the dose is calculated directly from the spectral information. For the first time the capability of a spectrometer and a survey meter are combined in a single and portable instrument.

## COMPARISON OF MEASUREMENT WITH CALCULATION

We measured the spectra and doses of the following three standard sources: <sup>36</sup>Cl, <sup>90</sup>Sr-Y, and <sup>137</sup>Cs. The measured spectra are shown in Figures 1 - 3. The solid curves in these Figures show the actual pulse-height distributions in MICROSPEC-2<sup>TM</sup>. The dashed curves show the spectra after correction for the detection efficiency of the spectrometer. The detection efficiency curve had been originally established empirically by comparing spectra from the phoswich spectrometer with spectra measured with a bare plastic scintillator where both the source and the scintillator were located inside a light-tight enclosure and under well-defined counting conditions. MICROSPEC-2<sup>TM</sup> uses efficiency-corrected spectra to compute the beta dose-rates. The doses from the measurements normalized to unit source strength are listed in Table 1.

Table 1. Measured and Calculated Doses

Radioactive source	Measured dose nSv/Bq	Calculated dose nSv/Bq
<sup>90</sup> Sr-Y	0.44	0.46
<sup>36</sup> Cl	0.49	0.52
<sup>137</sup> Cs	0.54	0.58

Figures 4 - 6 show the comparison between the measured (corrected for efficiency) spectra and the theoretical spectra for the three sources. Overall, the agreement is quite good down to about 200 keV. However, below this energy, there is a question whether the experimental or theoretical curve is more reliable. We have computed the theoretical doses by folding the theoretical spectra into the fluence-to-dose function in reference 4. These values are listed in Table 1 and are in good agreement with the measured values.

In order to assess whether the "measured" and "calculated" doses in Table 1 are

truly correct, we calculated the dose in a tissue cylinder of thickness 0.001 cm and 1 cm<sup>2</sup> area embedded in a 5.08 cm diameter by 2 cm 4-element tissue cylinder. The small tissue cylinder was located 0.007 cm from the front surface of the larger cylinder. Calculations were done for the same sources on contact with the front surface using the ITS code.

We found that the doses obtained this way were considerably higher (up to 30%) than the calculated values given in Table 1. The cause for this discrepancy is still being studied. One possible reason is that the above calculations were all done using a point isotopic beta source, while in almost all electron fluence to dose conversion coefficients calculations, broad electron beam was used<sup>(4)</sup>. These functions are used in the MICROSPEC-2 software. When we fold the ideal beta spectra to the fluence-to-dose functions, we used it as broad beam. In the real case, with beta source on the skin surface, the beta trajectories are radial rather than parallel. This would tend to increase the calculated dose. There is also the effect of back-scattering. Back-scattering depends on the substrate material and the source spectrum distribution<sup>(6)</sup>. The materials are not the same in the two calculations.

In Monte Carlo calculations of energy depositions, we need a finite size of tissue cell. We pointed out in an earlier paper<sup>(7)</sup>, that for an isotropic electron source, the absorbed dose depends on the cell size and shape. Table 2 listed the dose values for five sources as a function of cylinder thickness. For beta spectra (<sup>14</sup>C and <sup>99</sup>Tc) of low energy, the doses increase rapidly as thickness decreases. For higher energy beta spectra (<sup>90</sup>Sr-Y and <sup>137</sup>Cs) the changes are smaller. If we reduce the cross section area of the cylinder, we expect that the dose will also increase.

Table 2. Absorbed Dose as a function of cylinder thickness

Thickness (cm)	<sup>14</sup> C	<sup>36</sup> Cl	<sup>90</sup> Sr-Y	<sup>99</sup> Tc	<sup>137</sup> Cs
.100	.0052	.104	.333	.051	.188
.010	.0503	.675	.665	.346	.565
.001	.146	.807	.783	.533	.715

## CONCLUSION

MICROSPEC-2<sup>TM</sup> is a general purpose beta detector, the broad beam response functions are proper for the measurement of beta dose. Using MICROSPEC-2 with B-probe is a big improvement for skin dose assessment. However, in using the electror fluence-to-dose conversion function, we need a spectrum to resemble the true beta spectrum as closely as possible.

In the part II, we will consider a new data analysis method different from the current approach. We will perform Monte Carlo calculations for many radioactive isotopes with different end-point energies and different spectral shapes to determine an overall correction factor as a function of beta energy.

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# MEASURED BETA SPECTRUM FOR <sup>36</sup>Cl

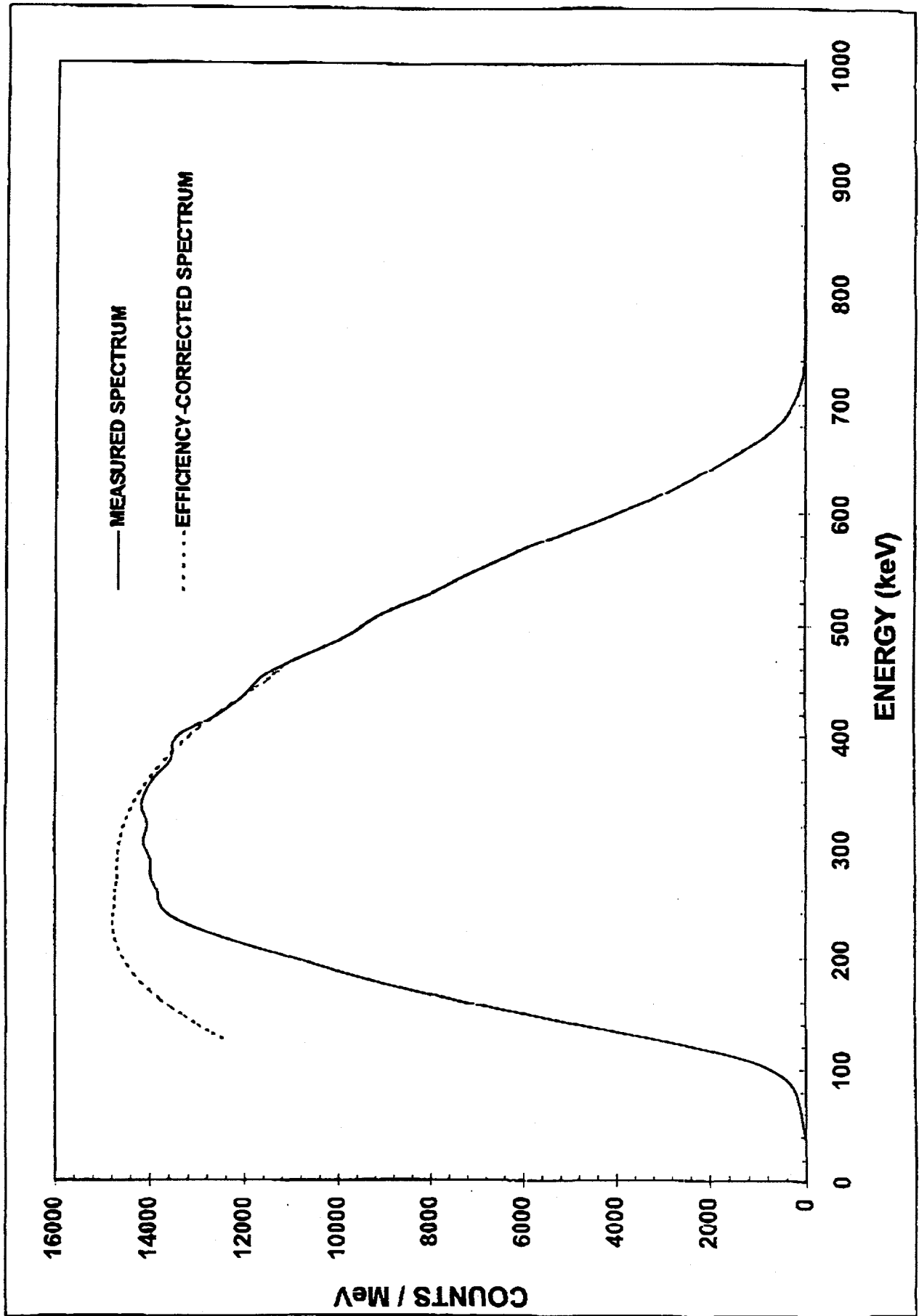


Figure 1.

# MEASURED BETA SPECTRUM FOR $^{90}\text{Sr}/^{90}\text{Y}$

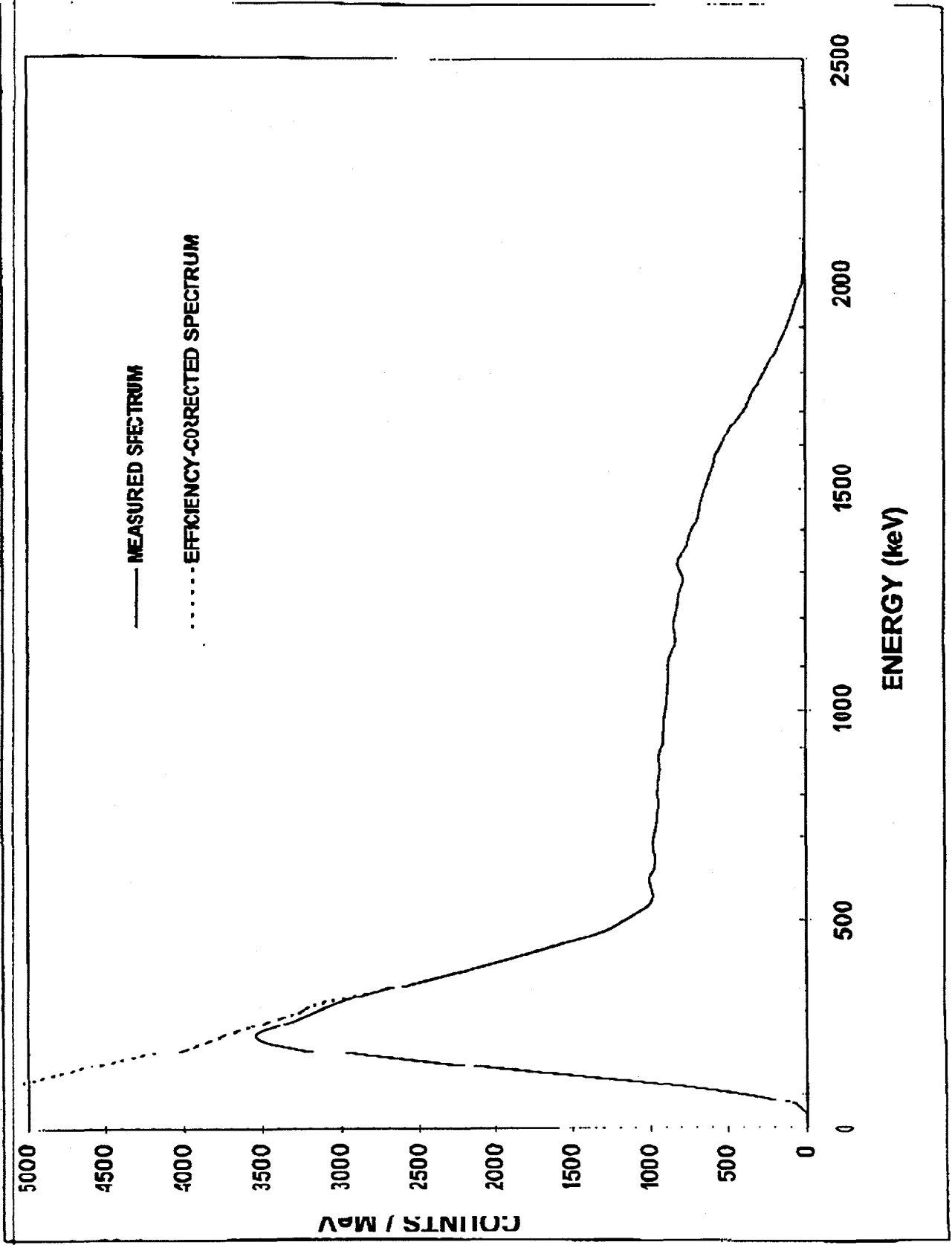


Figure 2.

# MEASURED BETA SPECTRUM FOR <sup>137</sup>Cs

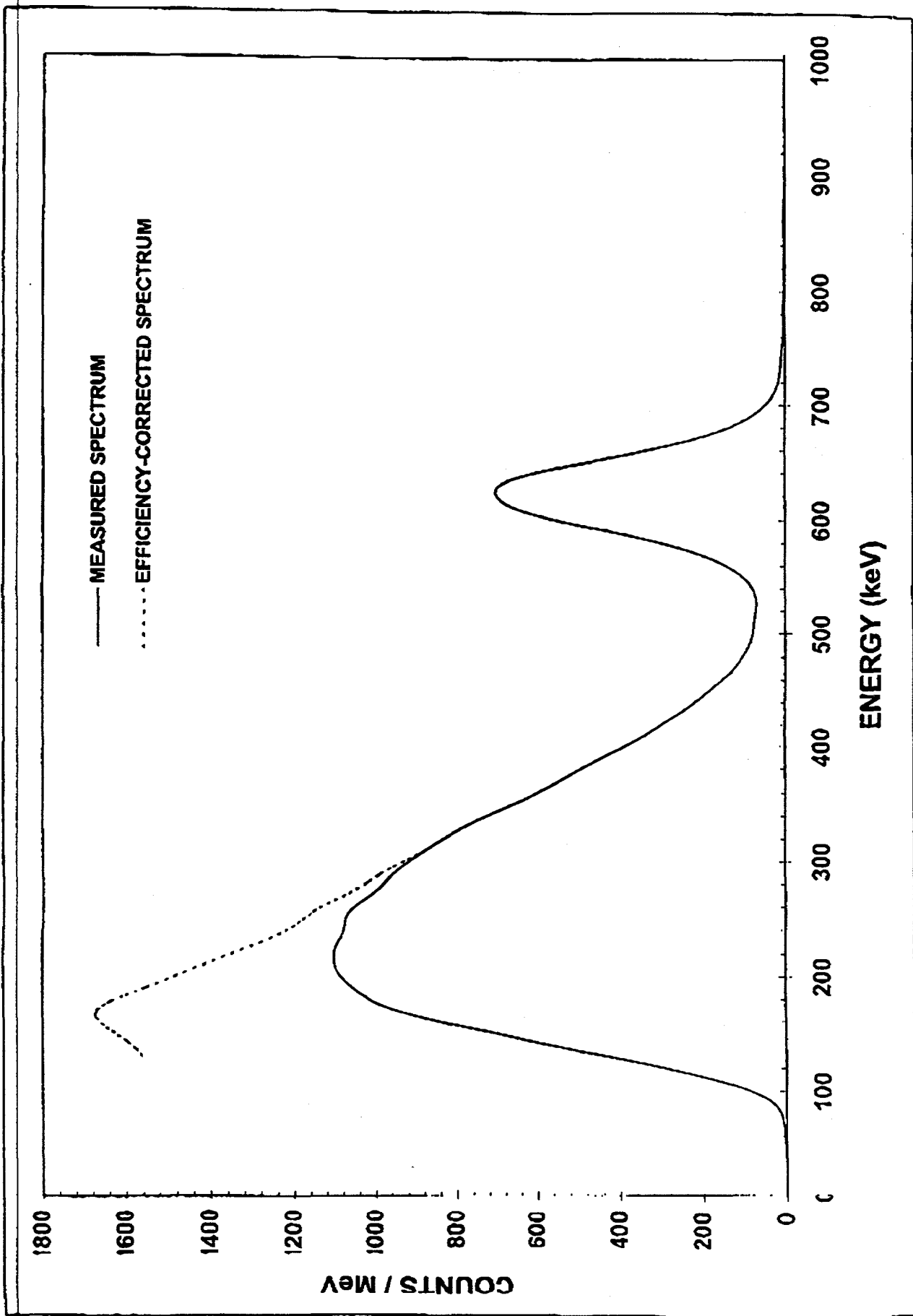


Figure 3

# COMPARISON OF MEASURED AND THEORETICAL <sup>36</sup>Cl SPECTRUM

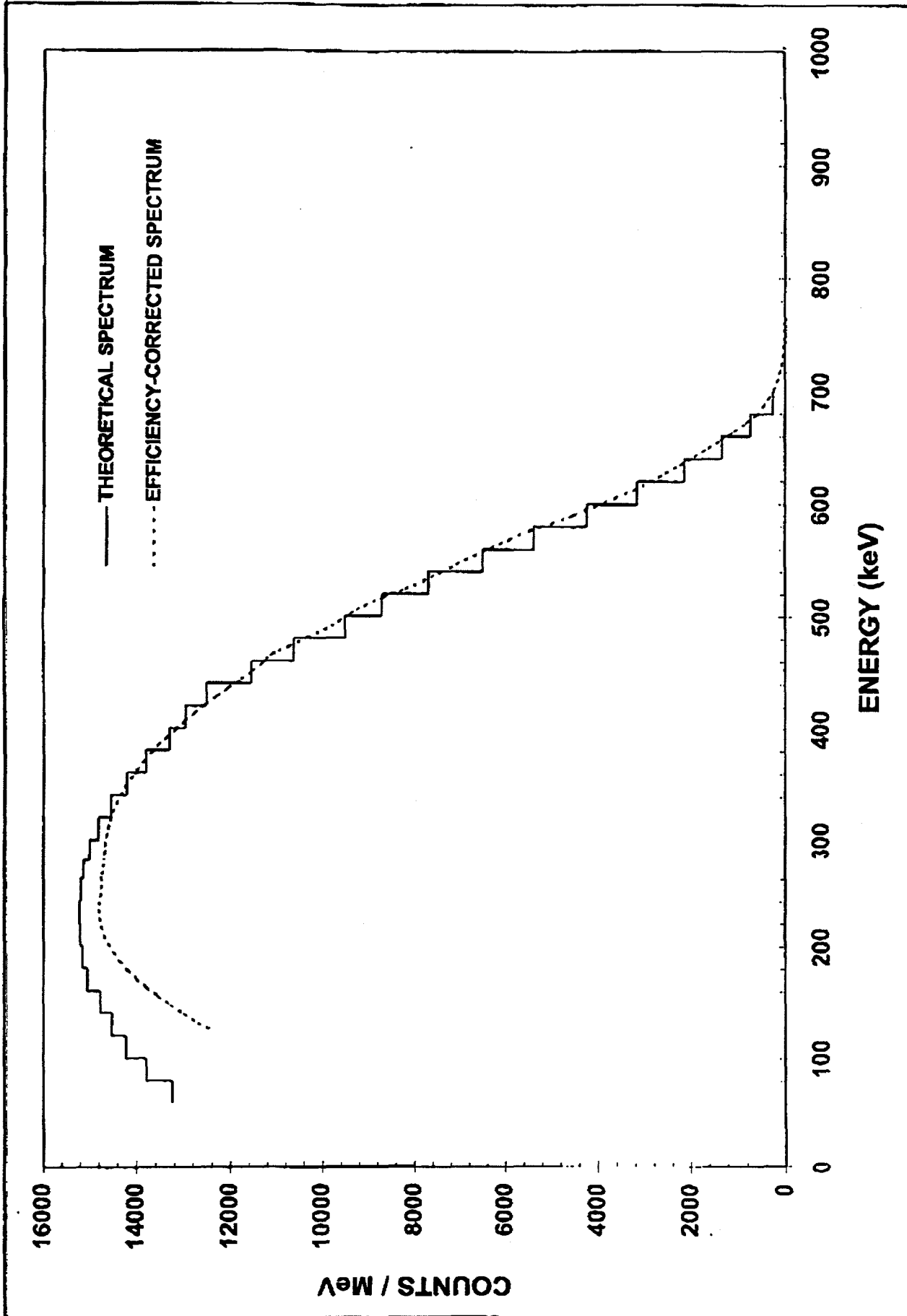


Figure 4

# COMPARISON OF MEASURED AND THEORETICAL $^{90}\text{Sr}/^{90}\text{Y}$ SPECTRUM

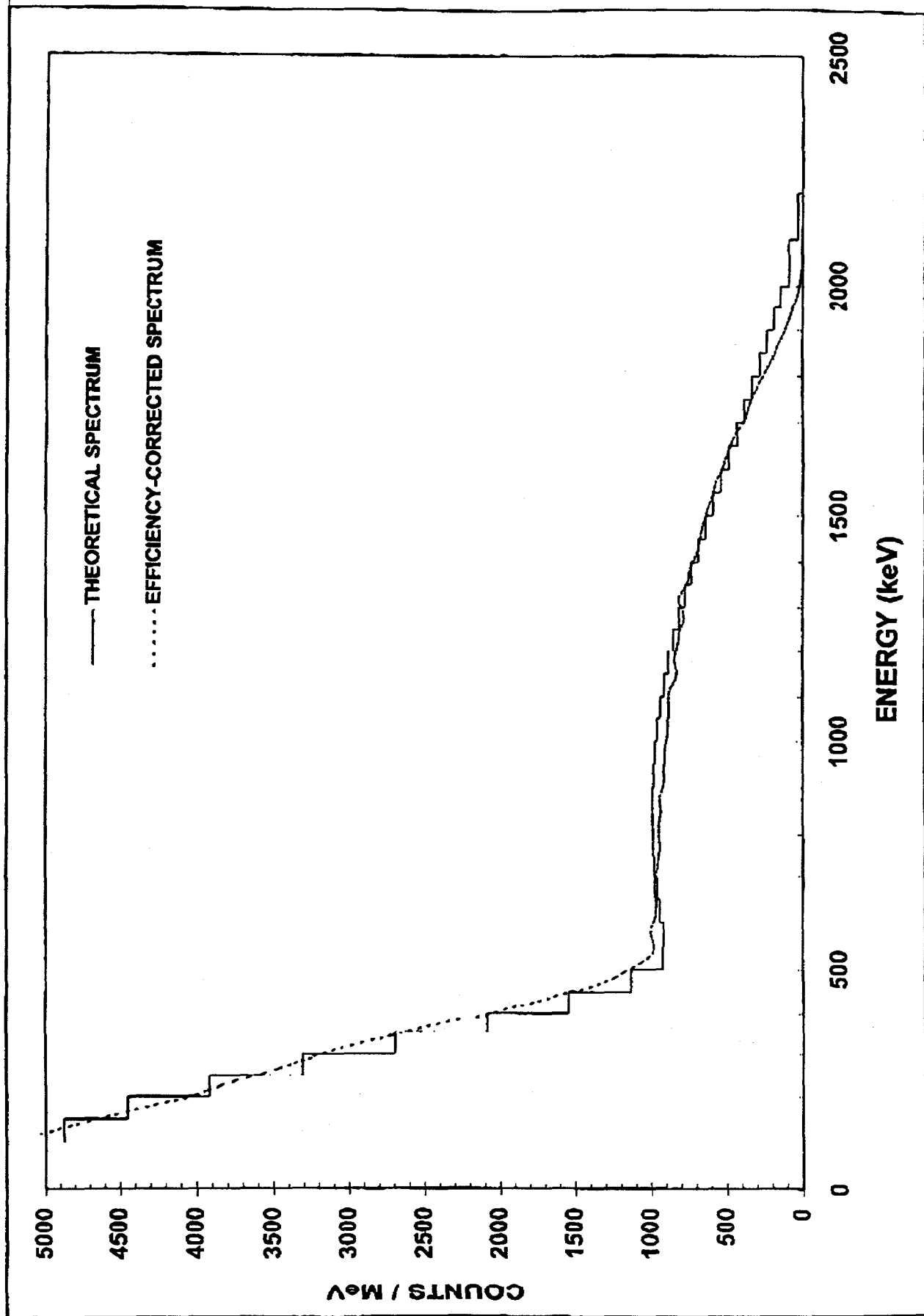


Figure 5

# COMPARISON OF MEASURED AND THEORETICAL $^{137}\text{Cs}$ SPECTRUM

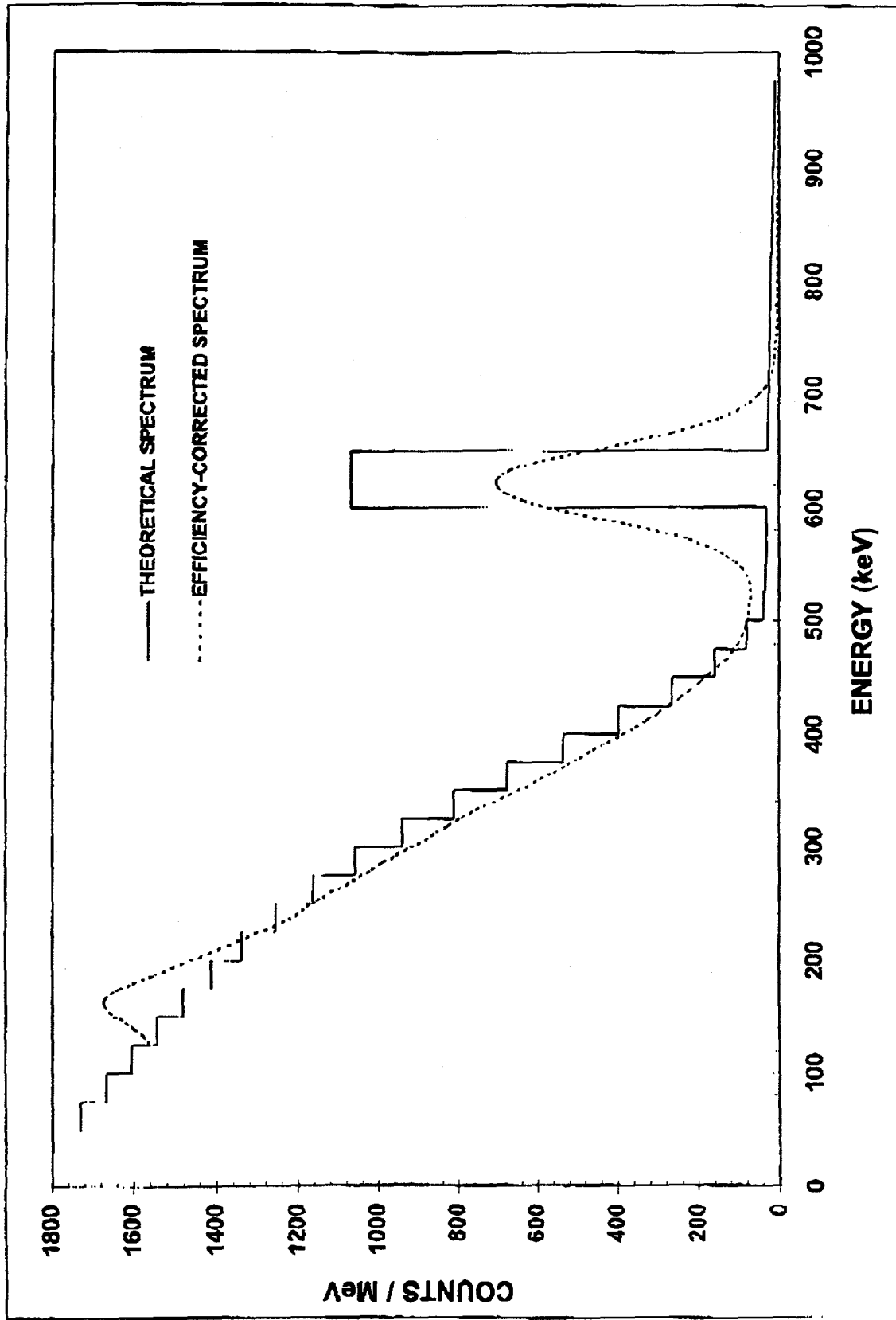


Figure 6