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Electron Energy Determination in Low Energy Van de Graaff Accelerator Beams

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The electron energy of 400 keV Van de Graaff accelerator was calibrated. The spectrum of mono-energetic electrons was observed by means of a solid detector and pulse height analyzer.

If one is interested in using electrons to study the fundamental defect-production process (which necessitates making measurements as a function of bombarding energies — e.g. the determination of the threshold displacement energy), then it is of crucial importance that the machine energy remain constant during the course of irradiation.

An electron accelerator having a maximum energy of less than 1.65 MeV is incapable of causing nuclear reactions and it is therefore usually calibrated by some method of range measurement.[1),2)] Sandwiches consisting of aluminum foil with some sort of sensitive paper in between are commonly used for this purpose, but such a measurement is usually accurate to only ±10% on a 1 MeV machine and is even worse in the case of 400 keV machine.[1)] The use of rocksalt single crystal to provide a "photograph" of the penetration profile is an improvement over aluminum foils. In other range measurement techniques, an absorbant material — usually an aluminum disk — is inserted between the beam source and a suitable electron detector such as a Faraday cup. An extremely good description of this method, along with a range-energy relation for electrons in aluminum is given by the Katz-Penfold equation,[3)] but there is a discrepancy of 6% between the experimental and theoretical values.[4)] Since it is necessary to position the absorber and detector in an evacuated system in order to obtain accurate experimental values, interchange of absorbers is a laborious task.

A better way to calibrate the machine, might be to have the machine produce a nuclear reaction whose energies have been identified. For energies below 1.65 MeV this means that the machine should be capable of delivering protons.[5)] Therefore, the machine would have to be converted to a proton source. It was estimated that the minimum time required to convert the machine from electron to proton operation would be three weeks, and a similar amount of time would be needed reconvert.

Therefore, a very accurate and more convenient method were developed at Brown University, a brief description of which follows.

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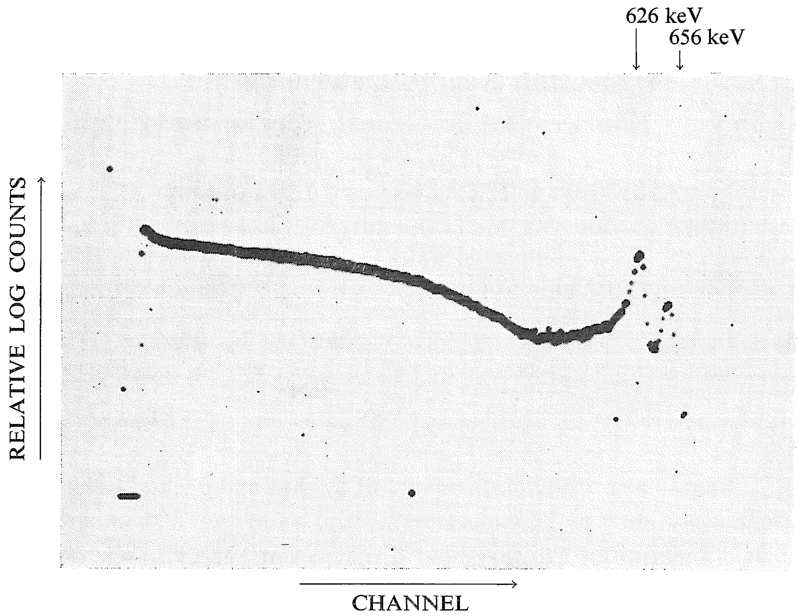

Cs^{137} Source.
Beta continuum: 514 and 1180 keV end point energy.
Conversion electrons: 626 and 656 keV.
Photons: 30 and 662 kev.

Fig. 1. The spectrum of conversion electrons from Cs^{137}.

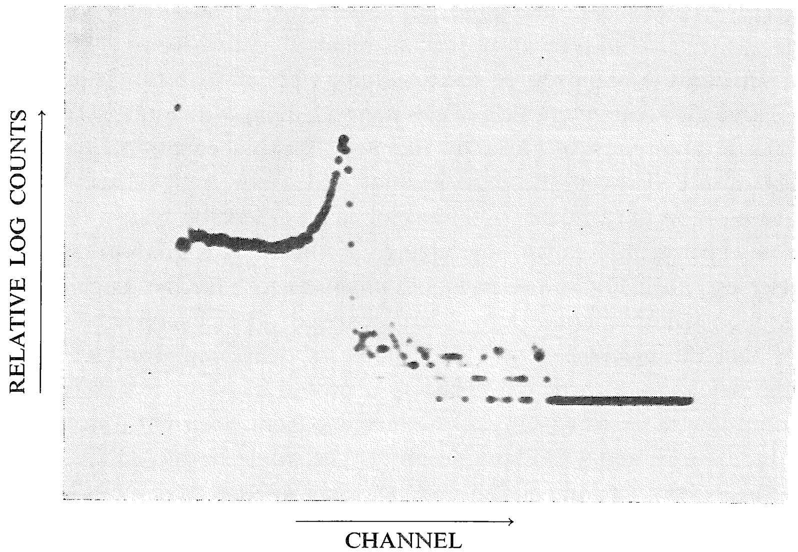

Fig. 2. The spectrum of electron beams from a 400 keV Van de Graaff accelerator.

The energy of an electron beam produced by a Van de Graaff accelerator (having a maximum energy of 400 keV) was calibrated. This was accomplished by comparison with monochromatic radiation from isotopes whose energies had been accurately identified. A silicon-crystal counter and a 256 channel pulse height analyzer system were used to measure the energies of the isotopes and of the Van de Graaff electron beam. This method is very convenient in that the energy spectrum can be seen on the cathode ray tube of the pulse height analyzer, at the same time that the teletype output-terminal prints out the count of each channel, thus accurately determining the peak channel. The internal-conversion electron-beam of the isotopically pure electron and gamma-sources of Co^{57}, Ba^{133} and Cs^{137}, firmly deposited on very thin plastic to minimize backscattering was used to calibrate the 400 keV Van de Graaff accelerator. A solid detector of negligible window thickness and sufficient sensitivity for beta rays was used. The spectrum of Cs^{137} taken by this detector is shown in Fig. 1.

It is important to use low beam-densities in order to avoid both radiation damage to the detector and a "pile up" effect, i.e., arrival of electron during dead time of the counting system. For this purpose a simple defocusing quadrapole magnetic lens system was used with a precision-made disc collimator, a plate of the latter being used as a current monitor.

The detector and pulse-height analyzer system were very stable throughout the duration of the one month experiment, with a drift of less than one channel.

One of the advantages of this method is that since the beam spectrum can be monitored directly as shown in Fig. 2, the monoenergetic characteristic of the Van de Graaff accelerator beam can be verified during operation.

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