

MEASUREMENTS ON SLOWING DOWN SPECTRA OF SECONDARY ELECTRONS IN ALUMINIUM AND COPPER FROM ^{60}Co γ -RADIATIONS

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Abstract—Spectral distributions of the fluxes of secondary electrons produced by a collimated beam of ^{60}Co γ -rays, inside media such as aluminium and copper for five different angles—30, 60, 90, 120, and 150°—relative to the incident direction of γ -rays, were experimentally determined using a lithium-drifted silicon detector.

Targets of the spherical cavity were used, having a circular opening exit on the cavity wall. Secondary electrons inside the cavity were extracted through the exit and absorbed in a silicon crystal. The target wall was of the thickness sufficient to ensure the electron equilibrium inside the cavity.

In order to subtract the background due to various sources, dummy targets were also used, which were of the same weight as the spherical targets and of the doughnut shape, for secondary electrons from the dummy targets not to reach the detector. The target and detector assembly was built in a vacuum chamber and the silicon crystal was cooled by liquid nitrogen.

The spectra were corrected for the spectral distortion due to the backscattering of incident electrons from silicon crystal, by using the back-scattering data obtained with an air core magnetic spectrometer over the energy range measured (25–1100 keV).

The results show that the electron spectra slightly differ between aluminium and copper and remarkably depend on the angles, that is, the higher energy components increase with the decrease of angles. This result is considerably of interest for the reason that the observed spectra are a kind of the black body radiation and was expected to be nearly isotropic.

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DISCUSSION

D. BLANG (*France*):

1. Quelle est votre opinion concernant l'emploi possible de détecteurs de silicium à barrière de surface et diffusion de lithium? Ils sont utilisables à la température ambiante et semblent pouvoir donner de bons résultats dans certaines des mesures dont vous avez parlé.

2. Pourrais-je avoir des détails concernant votre technique de fabrication des détecteurs à cavité du type "puits"?

J. LIPPERT:

1. Due to the low photopeak efficiency this will not be advisable except in the low energy range up to about 50 keV. I do not see however any reason to use silicon detectors, as germanium detectors with thin windows will be available in the near future.

2. You will find information on fabrication methods in the literature.

K. J. VOGT (*Germany*):

Für die praktische Anwendung bei der Abschätzung von Gefahren, die in Verbindung mit den Freisetzen radioaktiver Abluft von Reaktoren in die Atmosphäre entstehen, stellt das Modell der homogenen Kugelquelle eine zu grosse Vereinfachung dar. Hierbei muss die tatsächliche Verteilung der Radioaktivität der Wolke oder Abluftfahne aufgrund der meteorologischen Bedingungen berücksichtigt werden. Es soll in diesem Zusammenhang auf die Arbeiten von Holland und anderen Autoren verwiesen werden, bei denen die Vielfachstreuung über den Aufbaufaktor berücksichtigt wird. Die Bedeutung der vorliegenden Arbeit besteht nach meinem Verständnis darin, die Zulässigkeit dieser Prozedur zu bestätigen.

A. SCHMIDT (*Germany*):

Das Ziel der Arbeit war die Überprüfung der Genauigkeit des Dosiswertes, der mit Hilfe des Build-up-Faktors berechnet wird. Hierbei zeigte sich, dass der mit dem Build-up-Faktor berechnete Dosiswert mit grossen Fehlern behaftet ist, wenn die Entfernung der Wolke vom Beobachtungsort klein ist, d.h. in Luft kleiner als etwa 300 m. In der Literatur wird der Build-up-Faktor auch zur Berechnung der Dosis für Volumenquellen in geringer Entfernung benutzt. Die betrachtete Geometrie ist eine starke Vereinfachung der wirklichen Geometrie. In meiner weiteren Arbeit werde ich vorhandene Grenzen und Grenzsichten zwischen mehreren Medien berücksichtigen.

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P. CANDES (*France*):

Quelle est la proportion de la dose due au rayonnement diffusé, par rapport au rayonnement direct, à quelques km de la source?

A. SCHMIDT (*Germany*):

Die durch die direkte Strahlung verursachte Dosisleistung ist sehr viel kleiner als die Dosisleistung der gestreuten Strahlung, falls die Entfernung gross ist. Bei einer Entfernung von 1000 m–2000 m in Luft, d.h. ca. 10 mfp bei einer Energie von ca. 1,5 MeV, ist die Dosisleistung der direkten Strahlung ca. 15% der gesamten Dosisleistung.

F. BERTHOLD (*Germany*):

There exists another solution to the problem of continuous tritium monitoring, including gamma-compensation. A flow-through proportional counter may be used, constructed similarly to those used for age determination. An inner sample-counting volume is surrounded concentrically by a multiple-wire guard-counter volume, the two volumes being separated only by a cathode grid. The total volume is 1.3 liters, sample volume about 30%. A 1:1 mixture of the air to be measured and methane is pumped through the detector, and using an anticoincidence circuit only those pulses occurring in the sample counter itself are registered. This ensures that only particles with very short range are measured, and therefore the system is highly selective for tritium, and has very low background (10 cpm behind 1 cm of lead, less than 1 cpm behind 10 cm of lead). This instrument is similar to one described earlier by R. Ehret, H. Kiefer and R. Maushart, in "Direct Information" of the ESG/ESRP/SEPCR, 2/63. With coaxial construction the counting gas consumption is now considerably reduced. In both systems the sample counter "walls" consist only of an array of thin wires, thereby virtually eliminating memory effects, even for HTO. Gamma-compensation is achieved by subtracting from the anticoincidence count-rate a small and adjustable part of the count-rate of the guard-counter in a difference ratemeter.

A theoretically better approach would be to use the rate of coincident pulses for gamma-compensation because in this case one would not also subtract some of the pulses produced by tritium in the guard-counter. However, the performance of this simple gamma-compensation method has been proven to be practically equivalent.

A concentration of $10^{-7} \mu \text{ Ci/cm}^3$ can be detected, this being well below the MPC for tritium.

The complete tritium-monitor with detector, gas flow regulation and electronic system (consisting of standard transistorized modules according to the ESONE-system) and recorder is contained in three 19 in. racks, and it is already used successfully in a number of nuclear installations.

J. A. AUXIER (U.S.A.):

In view of the difference of opinion between experts, relative to whether the pulse height distribution for a given LET should be triangular or square in shape, I wonder if an empirical relationship of pulse height and QF would not only be justified, but desirable from an application point of view.

R. F. DVORAK:

I will answer this in two parts. First, we had studied these spectra using both triangular and square distribution assumptions. The numerical values for dose equivalent turn out surprisingly close, differing by perhaps 30% and depending on the spectrum studied. The LET distributions are also found to be very similar. It would seem that the choice is not crucial.

Second, Dr. Baum at Brookhaven has been working on just this question and mathematically at least there is such a relationship.

J. Booz (*Euratom*):

I have a question on the CO that has been used. What about the electronegativity of this gas? I wonder if you might lose some electrons and what might be the influence on the measured spectrum.

R. F. DVORAK:

Certainly many electrons are lost. All of the better tissue equivalent gases are quite electronegative. For the purpose of achieving stability it seems better to start with the more electronegative gas which is stable rather than a better gas and have rapidly changing multiplication.

N. ODA:

The slowing-down spectra of secondary electrons just inside the medium irradiated by Co^{60} γ -rays were measured for angles 30° , 60° , 90° , 120° , and 150° with Li drifted Si detectors. Specially careful consideration was required to set up the collimators which consist of the lead one and the U^{238} depleted metal. The backscattering effect of the Si detector was corrected for with the use of the data obtained with monoenergetic electrons coming from the air-core magnetic β -spectrometer. The results show that the difference between a copper target and an aluminium one were not remarkable, but the spectra shapes change remarkably with the angle relative to the incident γ -ray. For aluminium, one can see the traces of plural scatterings of the Compton peak electrons for small angles.