DOSIMETRY OF BETA AND LOW-ENERGY PHOTON RADIATION USING EXTRAPOLATION CHAMBERS AND THIN SOLID STATE DOSIMETERS

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Objective

For accurate dosimetry of beta and low energy photon radiations, a large number of specific requirements for measurement techniques have to be defined and appropriate calibration facilities realized because of the low penetrability of these radiations. The objectives of this project are aimed at identifying such requirements and realizing facilities to measure doses due to weakly penetrating radiations with greater accuracy and consistency than is possible at present.

The work of the contract comprises the following main objectives:
- establishment of a regimen for beta calibrations based on extended area sources that comply with ISO series 2 specifications;
- study and refine the extrapolation chamber measurement technique for beta dosimetry;
- characterization of beta radiation fields in terms of the directional dose equivalent rate, H'(d,alpha);
- development and characterization of thin solid state dosemeters for beta radiation;
- development of dosimetry of low energy photon radiation.

A calibration facility has been established for beta radiations for irradiation at different incident angles and at different distances from the source. An automated, computer controlled extrapolation chamber measurement method for determination of absorbed dose rate to tissue has been developed. The homogeneity of beta radiation fields of promethium-147 and ruthenium-106 rhodium-106 sources was studied using thermoluminescent dosimetry (TLD). The beta radiation from an extended ruthenium-106 rhodium-106 source was characterized in terms of directional dose equivalent rate for different distances from the source. Study of thermoluminescent materials for application as thin detectors for individual dosimetry of weakly penetrating radiations has been concentrated on the lithium fluoride: magnesium, copper, phosphorous phosphor due to its high sensitivity, excellent tissue equivalence for photon exposure, low intrinsic background, and low sensitivity to fast neutrons. A detector made from this material was studied for practical use. It is a promising dosemeter but a disadvantage is that the maximum heating temperature is limited to 240 C, implying that a relatively long heating period is required before reuse.

The experimental setup is composed of the extrapolation chamber and the equipment for the measurement of the ionization current. The chamber has been modified to be automatically operated through a microcomputer with software able to define or change many parameters. The radiation fields are provided by a thallium-204 extended area source. The dose homogeneity has been checked at 3 distances by a densitometric method after exposing unpacked photographic films. From the results, the ISO specifications are fulfilled for fairly large filed diameters but it seems risky to use the total diameter, the 10% decrease of the doserate being located on the outer ring of the beam. The flattening filters also give satisfactory results.

The main advantage in the use of extended area sources without flattening filters lies in the availability of intense doserates. For the same distances, measurements of available doserates have been performed. The numerical values show that high doserates are available, even with flattening filters, for Series II sources and that most of the usual needs for calibration of
The conversion factors are numerical data required for the determination of the angular response of radiation protection. For the practical calibration of dosemeters a practical phantom (a plexiglass slab) is appropriate. Without filters, the conversion factors for thallium-204 also depend on the calibration distance. With filters, the conversion factor values at a distance of 30 cm agree quite well with those already published with point beta sources.

During the CEC contract, a calibration set up for beta radiation from extended area circular sources and a facility for irradiation at different incident angles of the incident radiation on a phantom, as well as several source detector distances have been estabished.

The extrapolation chamber measurement method is the basic standard dosimetric method applied to beta dosimetry. An extrapolation chamber consists of two parallel plate electrodes. The main characteristics (collecting area, leakage current, saturation curve) of two chambers have been studied. An online computer carries out data acquisition, including ambient parameters, calculating tissue dose rate with the associated uncertainty.

Dosimetric characteristics of graphite loaded thermoluminescent dosemeters (Flu/C discs from VINTEN) have been studied with TOLEDO or a RIALTO reader to determine conversion factors making knowledge of the tissue absorbed dose at various angles easier.

An extended area strontium-90 yttrium-90 source has been acquired and a special holder designed for it. The holder has a threaded stud on one side into which a rod can be screwed to enable the source to be positioned in front on an extrapolation chamber.

The results of an intercomparison were used for the standardization of measurement procedures and evaluation techniques with extrapolation chambers. An extended promethium-147 source was used for the intercomparison. A protocol was established based on the principles agreed among all participants. Measurements of the directional dose equivalent with the strontium-90 yttrium-90 source have commenced. Measurements at a source to chamber distance of 30 cm and at alpha equals 0 degrees have been completed for several tissue depths. Analysis of the results is in progress.

For experimental work and for many routine calibrations beta ray sources are needed with energies and activities resulting in dose rates outside the range of sources in ISO series 1 which are commercially available. This study will therefore be directed to the development and realization of beta ray calibration facilities based on extended area sources that would conform to series 2 reference beta radiation specified by the ISO. The study will centre around two different source constructions: circular sources, 42 mm in diameter, now in use at CEA laboratories in France and square source, 40 mm by 40 mm, used at the NRPB in the UK. Sources incorporating beta emitting nuclides with maximum energies ranging from 0.156 MeV (14C) to 3.54 MeV (106Ru/106Rh) constructed accordingly will be acquired jointly by the participating laboratories (CEA Grenoble, CEA Fontenay aux Roses, CEA/FAR, NRPB and Risoe).

Appropriate holders for practical use with calibration set up will be designed and constructed (CEA/FAR, NRPB). The homogeneity of radiation fields and residual maximum beta energy at various calibration distances will be measured and the usefulness of beam flattening filters will be investigated.

Various experiments will be conducted with a view to establishing a common regimen for the extrapolation chamber measurement of absorbed dose rate to tissue due to beta radiation at different depths in tissue and for different angles of incidence, Dtd(0;alpha) (CEA/FAR, CEN Grenoble, NRPB, Risoe). The influence of different design parameters of extrapolation chamber on the results will be investigated, for example, the effect of collecting electrode area (CEN, Grenoble) and the thickness of entrance window (Risoe). Sources will be interchanged between the four participating laboratories with a view to comparing results obtained with the different designs of extrapolation chamber and that of measurement techniques used by the laboratories (CEA/FAR, CEN Grenoble, CEA/FAR, NRPB, Risoe).

Having established a common regimen for the extrapolation chamber measurements (among the participating laboratories) the main thrust will be directed to characterizing radiation fields from the sources (both circular and square construction incorporating 14C, 147Pm, 90Sr/90Y and 106Ru/106Rh nuclides) in terms of directional dose equivalent rate, Hd(0;alpha) by measuring the absorbed dose rate to tissue at different depths in tissue and for different angles of radiation incidence, Dtd(0;alpha) (CEN Grenoble, CEA/FAR, NRPB, Risoe).

Particular attention will be given to the evaluation of factors, to convert from absorbed dose rate to tissue at a depth of 0.07 mm and for normal incidence of radiation, Dtd(0.07;alpha), to absorbed dose rate to tissue at the same depth in tissue but different angles of radiation incidence, Dtd(0.07;alpha). The data obtained will be compared with similar data obtained for other types of source construction (eg the PTB-Buchler secondary standard point sources).

For individual monitoring of weakly penetrating radiation there is a need for thin tissue equivalent detectors with relatively high sensitivity. Highly sensitive TL materials (eg MgB4O7:Dy; LiF:Mg,Cu,P; and Li2B4O7:Cu [Risoe] and TSEE detectors based on LiF and BeO [CEA/FAR, CEN Grenoble]) will be studied with a view to their application in individual monitoring of weakly penetrating radiation.

The results of extrapolation chamber measurements will be used as benchmark for determining the response of detectors developed.

The part of the programme concerned with dosimetry of low energy photons, (energies below 15 keV) will commence during the second year of the contract. A facility for generating low energy X-rays will be established at CEA, Fontenay-aux-Roses and measurements with extrapolation chamber will be initiated to determine coefficients to convert from air kerma to directional dose equivalent, H'(0.07;alpha). The facility will be used for the development and characterization of thin solid state dosemeters for application into the dosimetry of low energy photons. The response of detectors to different angles of radiation incidence will also be investigated.
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