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Progress report on radiation dosimetry standards, facilities and related topics at NMi, 2005 – 2007

E. van Dijk
NMi Van Swinden laboratorium
The Netherlands

1. Introduction

The following sections present brief summaries on activities related to standards, facilities and calibration services at NMi Van Swinden laboratory over the period 2005 –2007 with respect to radiation Dosimetry. Research activities at NMi have been focused on absorbed dose to water for medium x-rays, low energy photon dosimetry and a start has been made for 3D dosimetry in complex and very small radiotherapy beams, used in IMRT and radio surgery.

2. Accommodation and facilities

In the second half of 2005 the re-installation of the irradiation facilities and measurement equipment at the new premises in Delft were completed. The extensive quality assurance measurement program and validation of the new irradiation rooms were carried out. The accreditation for EN17025 was confirmed for the new accommodation and measurement equipment set-up. Since this process has been completed primary level calibrations are being performed again.

3. Air kerma standard and facilities

3.1 Re-evaluation of wall and non-uniformity correction factors

In 2006, the correction for attenuation and scatter, using a ^{60}Co gamma ray beam, in the wall material for the 5 cm^3 spherical and 2.5 cm^3 cylindrical, graphite walled, ionization chambers were recalculated using the Monte Carlo code PENELOPE. The results and the related change in calibration factor for ^{60}Co calibrations in Kerma in air are given in NMi report nr: VSL-ESL-IO-2006/1, published by NMi website. The Monte Carlo calculations and measurements to determine the correction for attenuation and scatter in a ^{137}Cs gamma ray beam will be completed in the second half of 2007.

The correction for fluorescence radiation in the FAC for x-rays in the range from 50 keV – 320 keV will be determined in 2007, in close cooperation with the standard Dosimetry department of the University of Gent, Belgium.

3.2 EUROMET comparisons

EUROMET 738: *Intercomparison of the personal dose equivalent for photon radiation.* In this comparison a transfer ionization chamber has to be measured in terms of $H_p(10)$ in five different radiation qualities under specified radiation incidence conditions. According to the time schedule the measurements were performed in February/March 2007.
EUROMET project 813: *Comparison of air kerma and absorbed dose to water measurements of Co-60 radiation in radiotherapy.* The measurement protocol has been agreed upon. In practice two comparisons will run in parallel (for the quantity air kerma and the quantity absorbed dose in water respectively). Measurements to be carried out by NMi were completed in March 2007.

3. Absorbed Dose standards

3.1 Absorbed dose standards based on a water calorimeter

A water calorimeter has been developed as a primary standard for high-energy photon radiation. The calorimeter is transportable and can be used for absorbed dose measurements on different sites. It has been compared with the graphite calorimeter through it's long term reference value in the NMi ^{60}Co source. The calorimeter has been used to measure kQ factors in clinical photon beams ranging from 6 MV to 25 MV. In addition a direct comparison has been carried out at BIPM. The results of this comparison are still preliminary.

3.2 Absorbed dose standard for low-energy photon

In the last years the use of low energy photon sources became more relevant in radiotherapy. An example is the use of ^{125}I seeds in case of prostate cancer. At NMi a feasibility study has been started in 2007 to investigate the possibility of determining the absorbed dose to water for low energy, low dose rate sources. Some source and phantom geometries have been simulated with MC code PENELOPE, to investigate the interface effects that occur at the phantom-detector interface crossing of photons en electrons.

3.3 Three-Dimensional Dosimetry

Developments in radiotherapy are progressing fast. Treatment techniques such as Intensity Modulated Radiation Therapy (IMRT), TomoTherapy and radiosurgery considerably improve the treatment of cancer patients. Because of the increase in complexity of the dose delivery for these techniques, absolute dosimetry in a single point is more difficult and additional knowledge of the dose distribution in a 3D volume is necessary. In January 2007 a study on the feasibility of a 3D dosimetry system as a verification service of radiotherapy treatment planning for complex treatment techniques has been started. The scientific literature is investigated on available and suited 3D dosimeters and anthropomorphic phantoms. A plan for initial measurements for investigations on the feasibility of GafChromic EBT film as dosimeter has been made.

4. Key comparisons

A key comparison was carried out between the NMi and the BIPM of standards of absorbed dose to water for 60Co rays. Using three different ionisation chambers as transfer standards for an indirect comparison. The preliminary result of the indirect comparison gives a ratio $Dw_{(NMi)}/Dw_{(BIPM)}$= 0.9920, with an uncertainty of 0.48 % (k=2).

The primary standard of NMi, a water calorimeter, was used to perform a direct comparison on absorbed dose to water. The results of the direct comparison are still under evaluation.

The same set of ionisation chambers was used to carry out an indirect comparison on Kerma in air. The result of the indirect comparison is still under evaluation.

5. k_Q measurements in high-energy photon beams

The NMi primary standard for absorbed dose, the water calorimeter, has been used to determine kQ factors of 4 types of in total 24 cylindrical ionization chambers in clinical photon beams from 6 MV to 25 MV. The results obtained from these measurements have been used in the new NCS Code of Practice for high-energy photon beams together with other experimentally determined kQ factors.

6. Dosimetry and quality assurance of low-energy photon sources in brachytherapy

Since 2004 NMi cooperates with a working party of the Netherlands Commission on Radiation Dosimetry, which investigates the clinical practice of QA aspects related to the use of low energy photon (LEP) sources in Belgium and the Netherlands. The final aim of the working party is to publish recommendations for QC regarding the use of LEP sources in brachytherapy applications and to foster the development of a calibration facility for those sources in Belgium and the Netherlands. Part of the study was the verification of the source strength of LEP sources on location by a visiting team. Air kerma strength measurements were performed for all types of LEP sources currently in use in Belgium and the Netherlands using two commercially available measurement systems. Except for one source type both measurement systems were calibrated at NMi using NIST traceable sources of the types employed in Belgian and Dutch radiotherapy centres. The results measured by the visiting team were compared to measurements performed by the local medical physicist and to the source strength specified on the manufacturer's certificate. First results concerning the "on-site" visits will be presented on the forthcoming GEC-ESTRO-ISIORT EUROPE joint meeting in Montpellier, May 2007.

7. Publications (March 2005 – May 2007)

NMi report nr: VSL-ESL-IO-2006/1, Wall correction factors for cavity chambers and ^{60}Co radiation using Monte-Carlo methods
Eduard van Dijk, March 2006