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PROGRESS REPORT ON RADIATION DOSIMETRY STANDARDS, FACILITIES AND RELATED TOPICS at NMi, 2003-2005

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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 2003-2005 with respect to radiation dosimetry. Research activities have been focussed in this period on water calorimetry in x-ray beams, measurement of k_Q factors in clinical photon beams and the determination of correction factors for a primary standard for β-sources used in medical applications. The co-operation with the Netherlands Commission on Radiation Dosimetry (NCS) and with the Belgian and Dutch Societies for Clinical Physicists was continued. NMi is active in several NCS working parties dealing with topics in the field of dosimetry and quality assurance in radiotherapy and diagnostic radiology. From January/February 2004 NMi staff became increasingly involved in the program for the renewal of the accommodation of NMi.

2. Accomodation and facilities

As part of a large program to concentrate all existing measurement standards and facilities of NMi Van Swinden Laboratory in one refurbished accommodation in Delft new laboratories for the Ionizing Radiation section were built in Delft. Staff members were intensely involved in all technical aspects during the respective design and construction phases. The relocation of the standards developed to be the major event in the second half of 2004 and in the year 2005. The new laboratories comprise separate irradiation rooms for the teletherapy level ^{60}Co source, the multi-gamma source facility for radiation protection, beta dosimetry, a special laboratory for calorimetry and the 50 kV (including mammography) and 320 kV x-ray units. Furthermore new laboratories for radioactivity measurements were built.

In January 2005 all activities were brought to an end in Utrecht followed by dismantling all irradiation facilities, including the therapy level ^{60}Co source and 50 kV and 320 kV x-ray sets.In March 2005 all measurement standards and facilities were moved to new built laboratories at the premises of NMi in Delft. Re-installation of the irradiation facilities and measurement equipment is in progress. An extensive quality assurance program is carried out before and after the move to demonstrate that the realization of absorbed dose and air kerma quantities has not changed. Calibration services are expected to be resumed in Delft before the summer of 2005**.**

3. k_Q measurements in high-energy photon beams

In 2004 activities on the experimental determination of k_Q beam quality correction factors and beam quality specifiers $TPR_{20,10}$ and $\%dd(10)_x$ in high-energy photon beams of nine selected Belgian and Dutch radiotherapy institutes were carried out. The k_Q measurements involved four selected types of ionization chambers and the NMi water calorimeter. Six chambers of each ionization chamber type (manufactured by NE, PTW and Wellhöfer), in total 24 ionization chambers, were measured in all 9 clinical beams.

Progress of the measurement program was dependent on the behaviour of the NMi water calorimeter, which suffered from severe problems related to the water quality used in the high purity water (HPW) glass cell of the calorimeter. The problems with the water quality were also related to the malfunction of a commercial device used for purifying water. Furthermore the measurements suffered from delays caused by the relocation activities. Despite the difficulties most measurements were completed by NMi staff in co-operation with members of the NCS Subcommittee "Uniformity Dosimetry Protocols".

Preliminary results showed the need for additional measurements in two radiotherapy institutes. It is expected that absolute dose determinations in the ^{60}Co reference beam of NMi with the water calorimeter will be resumed in July 2005. The last phase of the k_Q measurement program comprises a recalibration of all ionization chambers in the ^{60}Co reference beam of NMi. The NCS subcommittee intends to use the measured k_Q data in the new NCS Code of Practice for the dosimetry in high-energy photon beams, which is currently drafted.

4. Air kerma standards and facilities

4.1 *Re-evaluation of wall and non-uniformity correction factors*
The primary air-kerma standards for ^{60}Co gamma rays at NMi are based on a 5 cm^3 spherical and a 2.5 cm^3 cylindrical graphite walled ionization chamber. The correction factor for attenuation and scatter in the wall material (k_{wall}) of these cavity ionization chambers is recalculated using the Monte Carlo code PENELOPE. The project was resumed in March 2003, but progress is slow. First results were achieved, but more refined calculations have to be carried out. Also the correction factor for axial non uniformity will be re-evaluated for both ionization chambers.

4.2 *EUROMET comparisons*
NMi participates in EUROMET project 545: *Intercomparison of NMI air kerma standards for ISO 4037 narrow spectrum series radiation qualities* (Tube potentials 30 kV to 300 kV). In March 2004 four transfer ionization chambers were calibrated for a number of a selected radiation qualities. The measurements were carried out in accordance with the agreed measurement protocol of the project.

NMi is also participating in two other EUROMET comparison projects. The first comparison is 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 measurements are foreseen in the period 2006/2007. The second comparison

is 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. 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 are scheduled in 2007.

5. Absorbed Dose standards

5.1. *Absorbed dose standard based on a water calorimeter*
The NMi (portable) water calorimeter was extensively tested in ^{60}Co gamma radiation and high-energy photon beams. Various correction factors were determined for photon radiation beams up to 25 MV.
The water calorimeter was used in a measurement program to determine k_Q factors in clinical high-energy photon beams of different medical linear accelerators at 9 selected radiotherapy institutes in Belgium and The Netherlands. New glass-coated thermistors are tested to replace the current thermistor probes in the future.

5.2 *Absorbed dose standard for medical beta ray sources*
The primary standard for calibration of ophthalmic applicators and sources employed in intravascular brachytherapy -a parallel plate extrapolation chamber with a very thin entrance window- is now in operation. An intercomparison with NIST by calibrating a ^{90}Sr-^{90}Y line source under phantom conditions is carried out. Results are expected in the second half of 2005.

5.3 *Absorbed dose standard for low-energy photon sources*
A special water phantom has been developed for measuring the dose rate of ^{125}I seeds. The seed is mounted in a parallel plane at well defined distances close to the surface of the water phantom and the seed can be rotated around its cylindrical axis. The water phantom including the seed can be accurately positioned to the entrance window of a plane parallel extrapolation chamber. Correction factors for the experimental setup are calculated using the Monte Carlo code PENELOPE and preliminary measurements to investigate the depth dose distribution in water are carried out.

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

A task group of the NCS in cooperation with NMi is currently drafting guidelines for quality assurance (QA) of low energy photon sources used in brachytherapy. The main goal of this work is to investigate current clinical practice of QC in brachytherapy in all radiotherapy institutions in The Netherlands and Belgium. Activities will focus on the verification of source strength, traceability aspects and the clinical application of treatment planning systems. QA teams will visit hospitals to investigate "in-house" QA and calibration methods and to perform dosimetric intercomparisons. On-site visits are intended to start in the summer of 2005.

7. Second national comparison of personal dosimetry services in the Netherlands

The aim of the comparison exercise was to examine the performance of the personal

dosimetry services. For different radiation qualities the quantity personal dose equivalent $H_p(10)$ had to be assessed by the participating personal dosimetry services from pre-irradiated dosemeters. The dosemeters were irradiated by NMi under specified laboratory conditions to an amount of dose equivalent, unkown to the participants. For every participant dosemeters were irradiated for ^{137}Cs, ^{60}Co and radiation qualities N-60, N-150, W-80, W-300, and a mixed quality of W-80/W-300 defined in *ISO/FDIS 4037-3:1999*. The mixed radiation quality was applied by varying the incident radiation from -80 degrees to +80 degrees in a horizontal plane with the beam axis in steps of 10 degrees. The results were expressed as the ratio of "measured" value of $H_p(10)$ by the participants and "true" value of $H_p(10)$ givan by NMi. The results were satisfactory for all participants.

8. ISO/IEC 17025 accreditation and status of CMCs

The radiation dosimetry calibration services are accredited by the Dutch Council for Accreditation (RvA). In June 2003 the Ionising Radiation Section was revisited by the RvA. No non-conformities were found and the accreditation was renewed. The quality system of NMi was presented to and approved by the QS-Forum Group of EUROMET. The radiation dosimetry CMC tables of NMi were submitted by EUROMET for inter-RMO review, as part of a batch of CMC tables of several European National Metrology Institutes. The batch (coded: EUROMET.RI.3.2001) has finally passed the inter-RMO review and after approval the CMC tables were published at the KCDB website. Research activities and calibration work at NMi are subject to periodic internal audits and management review.

9. Publications (April 2003- March 2005)

[1] Aalbers, A.H.L., de Prez, L.A., and Pieksma, M.W.H., Dosimetry of high-energy photon beams with the NMi water calorimeter, Proceedings of the Workshop on Recent Advances in Absorbed Dose Standards, August 19-21, 2003, Melbourne, Australia, see: http://www.arpansa.gov.au/absdos/proc.htm (file:aalbers.pdf)

[2] Witzani, J., Bjerke, H., Bochud, F., Csete, I., Denoziere, M., de Vries, W., Ennow,K., Grindborg, J.E., Hourdakis, C., Kosunen, A., Kramer, H-M., Pernicka, F., Sander, T. , Calibration of dosemeters used in mammography with different X-ray qualities: Euromet project No. 526, Radiat. Prot. Dosimetry 108, 2004, 33-45

[3] Bader, F.J.M., Damen, P.M.G, de Vries, W. and Pieksma, .W.H.M., The second national comparison of personal dosimetry services in the Netherlands (in Dutch), NMi report S-SL-IO-2004.02, March 2004

[4] Kollaard, R.P.; Dries, W.J.F.; van Kleffens, H.J.; Aalbers, A.H.L.; Marijnissen, J.P.A.; Piessens, M.; Schaart, D.R. and de Vroome, H., Quality control of sealed beta sources in brachytherapy, NCS Report 14, August 2004

[5] Van Dijk, E., Kolkman-Deurloo, I.K. and Damen, P.M.G., Determination of the reference air kerma rate for ^{192}Ir brachytherapy sources and the related uncertainty, Med. Physics 31(10), 2004, 2826-2833