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PROGRESS REPORT ON RADIATION DOSIMETRY STANDARDS, FACILITIES AND RELATED TOPICS at NMi, 1999-2001

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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 1999-2001 with respect to radiation dosimetry. During this period research activities on radiation dosimetry concentrated on the development of absorbed dose standards. In order to define and prioritise our radiation metrology program the ionising radiation section intensified its contacts with the (Dutch) user communities in industry, health care, science, etc. For the medical physics community the cooperation of The Netherlands Commission on Radiation Dosimetry (NCS) with NMi is the corner stone to promote the appropriate use of dosimetry methods in scientific research and practical applications. The NCS is now officially supported by the Belgian Hospital Physicists Association (BHPS). NMi publications mentioned in this report are available on the NMi web site at http://www.nmi.nl.

2. ISO/IEC 17025 accreditation

The CIPM mutual recognition arrangement (MRA) implies for national metrology institutes (NMI's) the participation in key comparisons as an operational quality system. To ensure that there is a common understanding in Europe of the requirements of ISO/IEC 17025, the INITIATION project was set up and started November 2000 with partial funding from the European Commission. In this project NMi has been chosen to be one of the first standard laboratories to be accredited according to ISO/IEC 17025. In the first half of 2001 four departments have been visited for an audit under the auspices of Dutch Council for Accreditation (RvA). In the second half of 2001 the other departments of NMi Van Swinden Laboratorium will be audited.
The Ionising Radiation Section took part in the first audits and has been visited by the RvA in March this year. The section passed the audits without any non-conformities.

3. Automation measurement facilities

Data acquisition and instrument control for most measurement facilities in use at the

Ionising Radiation Section of NMi have been automated in the past. Recently a project has started to renew the existing computer software. New computer software for calibration facilities will be developed based on the object oriented computer language Delphi. An important feature is the use of a database structure and the possibility to share program modules for instrument control and read out of measurement equipment. The software will also include applications for automated generation of certificates.

4. Air kerma standards and facilities

4.1. Facilities and calibration services

Two parallel-plate free-air ionisation chambers serve as primary standards for low and medium energy x-rays. The low energy x-ray facility (10-50 kV) consists of a Machlett AEG 50 tungsten anode x-ray tube and a Varian Mo anode x-ray tube both connected to a Pantak HF75C constant potential high voltage generator. The medium energy x-ray facility (50 –320 kV) consists of a Philips MCN 321 x-ray tube connected to a Philips MG324 constant potential generator. The primary air kerma standards for gamma radiation of ^{60}Co comprise of a spherical and a cylindrical graphite cavity chamber with volumes of 5 cm^3 and 2.5 cm^3 respectively. Irradiation facilities for gamma radiation include a ^{60}Co therapy-level medical unit (Siemens Gammatron 3) and a low scatter irradiation facility equipped with six ^{137}Cs and three ^{60}Co sources for protection level calibrations. A wide range of working standards and calibration services is available for x-rays and gamma rays used in medical (including brachytherapy) and environmental applications and in radiation protection.

4.2. Air kerma standard for ^{137}Cs gamma radiation

A spherical graphite ionisation chamber is under construction to serve as a primary standard for ^{137}Cs gamma radiation. During the last two years the different components of the ionisation chamber have been built. The design of the ionisation chamber is based on the primary standard ionisation chamber for ^{60}Co gamma radiation. The next step is to assemble the ionisation chamber and to measure its characteristics. We intend to complete the test measurements in 2001. In 2002 the characteristics of the chamber will be determined in a reference beam of ^{137}Cs. After the realisation of the standard an intercomparison with the BIPM will be scheduled.

4.3. Intercomparisons

The results of the comparison of primary air kerma standards for x-ray qualities used in diagnostic radiology have been published as NMi Report S-TS-2000-10 (April 2000). The comparison was carried out in the framework of Euromet (Euromet project 364). In a separate working paper to the CCRI(1) a summary has been given. Currently NMi is participating in Euromet project 526 entitled “Calibration of dosimeters used in mammography with different x-ray qualities”.This intercomparison project is coordinated by BEV.

5. Absorbed dose standards

5.1. Development of an absorbed dose standard based on a water calorimeter
NMi offers radiotherapy institutes calibrations in terms of absorbed dose to water in a therapy-level ^{60}Co gamma ray beam. The calibration measurements are traceable to the standard for absorbed dose to water at NMi. The absorbed dose standard is based on a graphite calorimeter combined with a transfer method to convert absorbed dose from graphite into water. In 2000 the development of a new absorbed dose standard based on a water calorimeter has started. Previous feasability studies have enabled us to gain experience with a prototype water calorimeter. The project comprises the construction and characterisation of a (transportable) version of a water calorimeter. The design is based on the sealed-water calorimeter of Domen (NIST). The water calorimeter consists of a computer-controlled water-cooled thermostat surrounding a high-purity water cell, which contains two thermistor probes. The calorimeter is presently being tested in the ^{60}Co gamma beam of NMi. In June 2001 a new 170 TBq source will be installed in the ^{60} Co irradiation facility. Various correction factors of the water calorimeter will be determined experimentally and with the use of Monte Carlo simulations. This year test measurements are foreseen in high-energy photon beams. The test measurements will be carried out in clinical photon beams and photon beams of the linear accelerator from the University of Gent (RUG). The water calorimeter will be compared with the graphite calorimeter of NMi. It is planned to perform measurements with the water calorimeter in the medical linear accelerator of BNM-LNBH.

5.2 Intercomparisons
An indirect comparison was carried out for the quantity absorbed dose to water between NMi and BIPM with three transfer ionisation chambers (NE type 2611A). Air kerma calibration factors were also determined as an additional consistency check. The determination of absorbed dose to water by NMi is 0.38% lower than the value determined by the BIPM. The comparison has been published as NMi Report S-TS-2001.01 (March 2001). NMi will participate in the international comparison of the dissemination of primary standards of absorbed dose to water for ^{60}Co gamma rays, as agreed on the last CCRI(I) meeting in 1999 between the BIPM and the NMI's of Australia, Austria, Canada, France, Germany, Italy, the UK and the USA.

6. Beta-ray standards

6.1. Protection level calibrations
The beta-irradiation facility is equipped with ^{147}Pm, ^{204}Tl and ^{90}Sr/Y sources, which are part of the beta secondary standard from Büchler. The sources are calibrated in terms of absorbed dose to tissue and traceable to the primary standard of PTB. The facility is mainly used for applications in personal dosimetry and the calibration of radiation protection instruments.

6.2. Primary standard for medical beta sources

The new standard will be based on the principle of a parallel plate extrapolation chamber with a very thin entrance window. When a sufficient small collecting electrode is used it is possible to measure the dose rate distribution of beta particle emitting sources used in medical applications (e.g. the use of ophthalmic applicators and sources employed in intravascular brachytherapy). At present a prototype chamber has been build. The collecting electrode together with the surrounding guard electrode is easily exchangeable. The extrapolation chamber can be equipped with two collecting electrodes with 1 mm and 4 mm diameter respectively. The isolation gap between the collecting electrode and the guard electrode has to be as small as possible, because it is a mayor source of uncertainty. In our prototype the gap width is 0.06 mm. The prototype is being tested in a soft x-ray beam and in beta radiation. Based on the test results the construction of the chamber will be improved. In co-operation with the Catharina Hospital Eindhoven and the Technical University Eindhoven a project has been started to develop dosimetry methods for clinical use and to develop transfer methods for absorbed dose (rate) calibrations based on the extrapolation chamber of NMi.

7. Revision of the Dutch codes of practice for reference dosimetry in radiotherapy

At present the Dutch codes of practice for dosimetry of high-energy photon and electron beams are based on air kerma standards. A working group of the NCS has been established to develop new protocols for reference dosimetry of high-energy photon and electron beams. The working group consists of Belgian and Dutch clinical physicists and members from the national standards laboratories in Belgium and the Netherlands. The new protocols will be based on standards of absorbed dose to water in a ^{60}Co reference beam and replace the current codes of practice described in NCS Reports 2 and 5. Part of the working plan is the determination of k_Q factors for high-energy photon and electron beams as produced by medical linear accelerators in Belgium and the Netherlands. The working group plans to tabulate k_Q factors for photon radiation based on measured values. This involves the measurement of k_Q factors for ionisation chambers in use in Belgian and Dutch radiotherapy institutes. This measurement program will be carried out by NMi and RUG in a selected group of radiotherapy institutes.

8. Dosimetry and quality assurance in brachytherapy

A joint task group of the NCS and BHPS in cooperation with NMi has developed and published a set of minimum requirements for quality assurance (QA) for brachytherapy in all radiotherapy institutions in The Netherlands and Belgium. Therefore the current QA practice was investigated by an extensive questionnaire. The accuracy of dose delivery and implant reconstruction was determined by performing phantom measurements in the radiotherapy institutions. Based on the results of the questionnaire and the phantom measurements and published international QA recommendations a set of minimum guidelines for QA in brachytherapy were formulated. The guidelines are published as NCS

report 13 (November 2000).