Recent activities in radiation dosimetry at the VNIIM
April 2007

I.A. Kharitonov, N.D. Villevalde, A.V. Oborin, S.A. Fedina, V.I. Fominykh, I.I. Tsvetkov

D.I. Mendeleyev Institute for Metrology
St. Petersburg, Russia

Introduction

This report is a short review of the laboratory activity during 2005–2007 in the field of photon and electron dosimetry national standards. The main characteristics of the primary standards in the field of radiation dosimetry maintained at VNIIM are presented in the table.

Quantity	Standard	Radiation quality	Measurement Range
Exposure and air kerma	Plane-parallel free-air ionization chamber IK 10-60	Low energy X-ray (10–50 kV)	$1\cdot10^{-6}$ – $4\cdot10^{-2}$ Gy/s
	Plane-parallel free-air ionization chamber IK 50-400	Medium energy X-ray (50–300 kV)	$5\cdot10^{-7}$ – $1\cdot10^{-3}$ Gy/s
	Graphite cavity chambers C1 and C30	Gamma-rays from ^{60}Co	$2\cdot10^{-6}$ – $3\cdot10^{-2}$ Gy/s
	Graphite cavity chambers C1 and C30	Gamma-rays from ^{137}Cs	$3\cdot10^{-6}$ – $8\cdot10^{-4}$ Gy/s
Absorbed dose to tissue	Extrapolation ionization chamber	^{204}Tl, ^{147}Pm, ^{90}Sr/^{90}Y beta sources	$1\cdot10^{-5}$ – 1 Gy/s
Electron flux, flux rate and fluence	Faraday cylinders CF-3 and CF-REP Diamond detector AlD-1	Electron radiation up to 50 MeV	$1\cdot10^{10}$ – $1\cdot10^{21}$ s^{-1} $1\cdot10^{8}$ – $1\cdot10^{19}$ cm^{-2} s^{-1} $1\cdot10^{9}$ – $1\cdot10^{21}$ cm^{-2}
Energy flux, energy flux rate and energy fluence of electrons	Energy flux calorimeters: CP-1 and CCF Thick wall ionization chambers: ICB-6 and ICB-6M	Electron and bremsstrahlung radiation up to 50 MeV	$1\cdot10^{-4}$ – $1\cdot10^{3}$ W $1\cdot10^{-5}$ – $1\cdot10^{2}$ W·cm^{-2} $1\cdot10^{-3}$ – $1\cdot10^{3}$ J·cm^{-2}

The basic directions of the dosimetry laboratory activity:

The dosimetry laboratory is a part of VNIIM ionizing radiation measurements department and its main directions of activity are:

- research for improvement of the standards and transfer the unit sizes from the national primary standards to the secondary and working standards;
- international cooperation;
- calibration and verification of dose measuring instruments, radionuclide sources, measurement systems, devices, units;
- testing of dose measuring instruments, radiometric and spectrometric equipment for their type approval;
- radiation safety observance certification of products which include generating and radionuclide sources;
- normative documents formalization, ionizing radiation dosimetry measurement methods and verification procedures development.

1 Research work

1.1 Air kerma standards for x-ray and gamma radiation

In 2004 VNIIM purchased new x-ray apparatus ISOVOLT HS-320 for the medium energy x-ray standard. For 2005–2007 standardized radiation qualities spectral characteristics investigations have been carried out. Free-air ionization chambers correction factors improvement has been done.

Technical project for replacement the low-energy x-ray source and standard measuring equipment with modern facilities to be done in 2008–2009 has been developed.

In 2005 VNIIM obtained new ^{60}Co gamma-ray source (0.18 TBq) for gamma-ray protection-level measuring instruments calibration. At the same time new ^{60}Co gamma-ray source (160 TBq) was installed in "LUCH–1" unit of the Central Research X-Ray-Radiological Institute of the Ministry of Health Protection (CNIRRI) of Russia. VNIIM used "LUCH–1" unit in air kerma comparisons of radiotherapeutic ^{60}Co radiation.

VNIIM exposure and air kerma standard for ^{137}Cs and ^{60}Co gamma radiation is based on two graphite cavity chambers C1 and C30 constructed more than 30 years ago. In 2006 key comparisons COOMET.RI-K1 brought to light the problems of these chambers further application. So the decision to replace these chambers by new absolute graphite cavity chambers with the same parameters has been carried out. VNIIM considers (looks forward) the possibility of ND 1005 type chamber acquisition.

C1 and C30 chambers correction factors research and improvement is held in VNIIM using Monte Carlo simulation. MM C3D.exe software developed at the St. Petersburg Polytechnical University and EGSnrc software is applied.

1.2 Absorbed dose standard for beta radiation

In 2005–2007 the possibility to extend the range of absorbed dose rate measurements to low values was investigated. The correlation between the absorbed dose rate to tissue and beta-particle flux from the surface of ^{90}Sr+^{90}Y source has been determined.

Re-determination of the correction factors relevant to extrapolation chamber and used in calculation of the absorbed dose rate of beta radiation to tissue was made in accordance with the requirements of ISO 6980-2:2004(E).

1.3 Primary standard for flux, flux density and fluence of electrons, flux energy, flux density energy and fluence of energy electrons and bremsstrahlung radiation for energy up to 50 MeV

VNIIM has a measuring system using charge, calorimetric, electro-physical and ionization methods for electron accelerator with maximum electron energy up to 50 MeV and bremsstrahlung radiation field main parameters determination. The system includes Faraday cylinder as primary detector, calorimeter-Faraday cylinder, calorimeter of total absorption, thick-wall ionization chamber, magnetic induction converter, diamond detector. The system is used for main field parameters of industrial and medical accelerators electron and bremsstrahlung radiation measurement instruments calibration (verification).

In 2005–2007 there were performed:

- experimental investigations of calorimetric primary detector for energy flux and energy flux density of ^{60}Co source (310 TBq) photon radiation metrological characteristics; improvement of the upper range limit of energy fluence and flux density energy for 2,37 W and 0,188 W/cm^2 correspondingly and absorbed energy rate in graphite up to 3,59 W/g (absorbed dose rate up to 800 Gy/min) units reproduction;
- comprehensive investigations of calorimetric and ionization measurement channels in the field of accelerator-sterilizer with maximum energy of 3 and 10 MeV at the energy flux of 900 W, energy flux density of 14.8 W/cm^2, electron flux of 2,10·1015 s^{-1}, electron flux density of 4,52·10^{13} s^{-1}·cm^{-2} and absorbed dose rate in aluminum of 4,87 kGy/s.

2 International cooperation

In 2005 VNIIM took part in COOMET.RI-K1 key comparisons of air kerma standards for ^{60}Co gamma radiation under COOMET Project № 318. For the moment the comparisons are completed. Draft A was prepared and submitted to COOMET TC 1.9 IR for approval by PTB pilot laboratory.

VNIIM is participating in EUROMET.R(I)-K1 regional key comparisons under Project № 813. VNIIM air kerma primary standard measurements will be held in 2008.

VNIIM is participating in EUROMET project № 739 (BIPM KCDB: EUROMET. R(I)-K1) comparing standards of the absorbed dose to tissue for beta radiation. The measurements were completed at the end of 2005 г. At present time the final results are expected.

In 2005 and 2006 VNIIM was involved to the Program IAEA/WHO TLD postal dose quality audits for radiotherapy level dosimetry of ^{60}Co beam and high energy X-ray beam of linear accelerators in the Oncological Centers of St.Petersburg.

On September 20, 2005 VNIIM received the Certificate of Recognition of the Quality Management System in accordance with Standard ISO/IEC 17025 under the 6-th Technical Committee Meeting of the COOMET Quality Forum.

3 Measurement instruments calibration and verification

VNIIM supports measurements traceability to the national standards for a network of laboratories which provide verification (calibration) of dose measurement instruments for x-ray and gamma radiation protection level. VNIIM provides the same service for manufacturers of measurement instruments, as well as for test centers and medical centers using ionizing radiation for diagnostics and radiation therapy. This traceability is realized by the system of secondary measurement standards periodically compared (once per four years) with the national primary standard.

For the last two years the comparisons of air kerma (exposure) secondary standards for x-ray and gamma radiation of State Research Centers of Russia were performed.

More than 1100 verification and calibration procedures of reference and working dosimetry instruments and radionuclide sources (^{137}Cs, ^{60}Co, ^{226}Ra, ^{90}Sr/^{90}Y, ^{204}Tl, ^{147}Pm, ^{63}Ni, ^{3}H) from research centers, medical establishments and radionuclide products manufacturers were carried out.

Investigation and calibration of the alanine detectors in photon and electron radiation fields of accelerators for medical instruments and materials sterilization for air kerma up to 10 kGy were performed.

4 Measurement instruments type approval tests

There is no agreement concerning product certificates recognition between Russia and other countries including EC. According to the procedure in Russia all foreign measurement instruments should be tested for adequacy to both Russian and international standards. If the results of testing are positive the instruments are introduced into the State Register of the means of measurement and authorized for application in Russia. This rule is obligatory for Russian manufacturers too. Thus, all measurement instruments authorized for application in Russia have passed the tests for type approval.

VNIIM is the State Center of Tests in Russia of various types of measurements, including ionizing radiation measurements. During 2005–2007 more than 40 Russian and foreign measurement instruments for dosimetry, radiometry and spectrometry were tested for compliance with technical documentation and standards. There are x-ray diagnostic kits DIAset UNIVERSAL X-ray QC (“PTW-Freiburg”, Germany), x-ray dosimeters SOLIDOSE 300 (“RTI Electronics AB”, Sweden), dosimeters RADIAGEM 2000 and RADIAGEM 3 (“Canberra”, France), personal dosimeters DIN-01 (“INTRA”, Russia), multifunctional dosimeters MKC-AT1117M (“Atomtekh”, Belarus).

5 Products radiation safety observance certification

Certification procedure which includes functional parameters and radiation safety testing is applied to the equipment which is not a measurement instrument, but exploits ionizing radiation or is applied to the ionizing radiation fields.

For example, in 2005–2007 the following equipment was certificated:

- x-ray complexes for the Customs x-ray control: x-ray TV complex “Kolibry 150-TV”, hand-held scanner “WATSON” (“FLASH ELECTRONICS” Ltd., Russia);
- pedestrian portal radiation monitors “DOZOR” and transport monitors “RUBEZH” for nuclear materials and radioactive substances detecting (FGU Research and Technical Center “NFI”, Russia).

6 Normative documentation development

Development of instrument calibration and verification methods and procedures for fields and sources of ionizing radiation parameters measurement is one of VNIIM activities supporting the traceability of measurement results.

During 2005–2007 the following procedures have been developed in VNIIM:

- measurement instruments verification for measuring channels of atomic power-plants radiation control systems calibrated without dismantling or with partial dismantling;
- radiation output, half-value layer, radiant dose linearity at given anode voltage and other measurements for regular and routine control of medical x-ray equipment operating parameters in the diagnostic and radiation monitoring centers;
- general quantities measurements of medical and industrial accelerators radiation fields.

Reports and publications (2005-2007)

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9. V.I. Fominykh, Memories of the Teacher, *Sellection of scientific articles "In commemoration of Prof. K.K. Aglintsev"*, Saint Petersburg, 2006

10. I.A. Kharitonov, N.D. Villevalde, A.V. Oborin, E.N. Yuriatin, V.I. Fominykh, S.A. Fedina, I.I. Tsvetkov, The VNIIM activities on Radiation Dosimetry 2003-2005 *CCRI (1)/05-40*