Progress Report on Radiation Dosimetry at NPL

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April 2001

1 Calibration Services

The current range of radiation dosimetry calibration services provided by NPL is summarised in Table 2, at the end of this report. The majority of these services now have independent third party (UKAS) accreditation, although a number are at present under "voluntary suspension" from the UKAS Schedule, because of the various building moves occurring within NPL. Under UKAS rules, the services cannot be reinstated on the Schedule until formal approval of the service in its new location. In order to avoid delaying calibrations, a number of services will issue NPL, rather than UKAS, certificates for a short period.

2 Air Kerma Standards and Calibration Service

2.1 50 kV Free Air Chamber

The new large volume free air chamber for use at protection level air kerma rates is now fully operational. It was used in conjunction with the smaller volume chamber during the autumn 2000 calibration period and the two chambers again showed agreement of between 0.1% and 0.4%. The larger volume chamber was involved in a comparison carried out at NIST in October 2000 between NPL and NIST air kerma standards.

2.2 300 kV Free Air Chamber

The 300 kV free air chamber was involved in a comparison carried out at NIST in October 2000 between NPL, NRC and NIST air kerma standards. The exercise involved the dismantling of the chamber for transport and the reassembly for the comparison. The quality assurance measurements after the return to NPL demonstrated the stability of the design.

2.3 Cobalt-60 Cavity Chambers

The current cavity standards used at NPL are over 40 years old and there have been some difficulties in using them at protection level air kerma rates. The recent work on high dose brachytherapy source calibration has also shown the difficulty in using these standards at lower air kerma rates. In the light of these problems NPL has decided to build new cavity primary standards. The report on the design specification is nearing completion and detailed design is expected to begin in the autumn.

2.4 Comparisons

A comparison was carried out at NIST in October 2000 between the NPL and NIST low energy air kerma standards. The NPL 50 kV large volume free air chamber was compared to both the "Ritz" and "mammographic" free air chambers over a range of qualities. At the same time a comparison of the medium energy air kerma standards took place between NPL, NIST and NRC. A report is in preparation.

NPL is currently involved in a EUROMET comparison of air kerma standards at mammographic qualities. The comparison will be made via transfer standards circulated to each participating laboratory. The NPL measurements are expected to be performed in April 2001 and the comparison completed by November 2001.

2.5 Brachytherapy source calibrations

Work is continuing to establish traceability to the cavity primary standards. The work has demonstrated the difficulty in making measurements with the current chambers due to their age and small volume. It has been decided to build new cavity standards and to include measurements with the high doserate ^{192}Ir brachytherapy source in the design remit.

3 Beta-ray Standards

3.1 Protection Level

The work on maintaining the protection level beta-ray primary standard was not funded in the current UK National Measurement System Ionising Radiation Programme (1998-2001). It is not feasible to move the current primary standard from its present location and so it will be finally decommissioned when the move to a new building takes place in June 2001.

3.2 Ophthalmic Applicators

The primary standard extrapolation chamber with the new collecting electrode has continued to function satisfactorily and shows no sign of the radiation damage that destroyed the original electrode. Measurements with the quality assurance source show much better reproducibility with the new electrode design than with the original.

Work is continuing on extending the measurements to curved applicators using alanine dosemeters as transfer standards, and a calibration service is expected to be operational next year. The results achieved using new thinner (0.6 mm) alanine pellets have shown better reproducibility than those achieved previously with thicker pellets.

4 Absorbed Dose Standards and Calibration Services

4.1 Electron beam dosimetry standards

The primary standard electron beam graphite calorimeter was compared with the primary standard photon graphite calorimeter in a 16 MeV electron beam. Agreement was obtained within 0.2%, which indicates no significant systematic errors in either device, as the two calorimeters have very different construction and modes of operation.

A graphite calorimeter, based on the electron beam primary standard, was constructed for ARPANSA, Australia.

4.2 Electron beam absorbed dose calibrations

A new working party of the IPEM (Institute of Physics and Engineering in Medicine) has been formed (including NPL staff) with the remit to write a new UK Code of Practice for electron beam dosimetry, based on the calibration service developed at NPL. A number of chambers were calibrated against the primary standard calorimeter for members of the working party, enabling a comprehensive comparison of the present air kerma-based Code of Practice and the absorbed dose-based service. The new Code of Practice is currently in its final draft and it is hoped it will be published during 2001.

In parallel with this, NPL staff are currently carrying out a program of electron dosimetry audits of UK radiotherapy centres. The aim of this program is twofold - firstly to ensure uniformity of dose delivery across the UK; and secondly, to compare the response of different chamber types in electron beams from Linacs from different manufacturers.

4.3 Clinical collimator

A Varian clinical collimator is being installed on the NPL Linac in order to provide beam qualities closer to those produced by clinical accelerators. The head is intended to replace the current system of approximating clinical beams by the use of aluminium filters. In order to fit the collimator onto the existing Linac, it has been necessary to separate the unit into its component parts i.e. the primary collimator, target, beam flattening filter and secondary collimator. Characterisation of the beam is expected to take place during the summer 2001.

4.4 Water calorimeter

Good progress has been made on the project to develop a water calorimeter at NPL. The temperature enclosure has been improved to include a cooling coil at the beam entrance window of the phantom. This enables the air at the front of the phantom to be controlled, resulting in reduced sensitivity to changes in ambient temperature.

The design of the NPL water calorimeter is significantly different from other calorimeters in current use. As part of the design verification, an experiment was carried out to compare its repsonse with a calorimeter of the more conventional Domen design. In a 10 MV photon beam the difference in the temperature rise per monitor unit between the two calorimeters was 0.5%, with an uncertainty of 0.9%.

4.5 Alanine Dosimetry

A number of refinements have been made to the method of production of alanine pellets. In particular, a method has been devised to produce thin pressed pellets with thicknesses as low as 0.5 mm. These pellets are being used as a transfer system in the calibration of ophthalmic applicators and are also used for the calibration of low energy (≈1 MeV) industrial electron beams.

A programme of work has been started to use alanine dosimetry to compare absorbed dose determinations made from the electron beam and photon calorimeters. The objective is to ensure consistency between NPL absorbed dose calibrations derived from different primary standards. Alanine calibrated directly in a replica core of the electron beam calorimeter can subsequently be used to compare absorbed dose measurements derived in the conventional way from both photon and electron beam calorimeters.

A bilateral comparison with NIST was carried out at industrial (kilogray) dose levels using alanine dosimetry in March 2000. The comparison was carried out using Co-60 radiation and agreement was found within 0.5%.

5 Ratio of N_{DW}/N_K

The ratio's N_{DW}/N_K for all therapy-level secondary standard calibrations performed at NPL between 1988 and 2001 have been analysed and are summarised in Table 1. Where a given chamber was calibrated in terms of both air kerma and absorbed dose during the same calibration period (i.e. the calibrations were separated by at most two months), the ratio of calibration factors has been taken. Air kerma calibrations prior to 1992 have been revised so that all data are consistent with the current NPL standard. No significant variation has been found within the NPL Secondary Standard chamber type. Nor have we been able to confirm any difference between the two versions of this chamber, NE 2561 and NE 2611.

Table 1

				N_{DW}/N_K	
Chamber Type[3]	Sample size	Air kerma quality[1]	Absorbed dose quality	Mean[4]	Standard deviation (sample)[2]
NE 2561	41	2MV X-rays	^{60}Co γ-rays	1.0947	0.25%
NE 2611	4	2MV X-rays	^{60}Co γ-rays	1.0966	0.26%
NE 2561	37	^{60}Co γ-rays	^{60}Co γ-rays	1.0925	0.13%
NE 2611	19	^{60}Co γ-rays	^{60}Co γ-rays	1.0926	0.14%
NE 2571	1	^{60}Co γ-rays	^{60}Co γ-rays	1.0982	-

Notes

1. The NPL 2MV X-ray Van de Graaff facility ceased to function in 1996 and, since then, air kerma calibrations have been performed in ^{60}Co γ-rays. The X-ray output of this machine was less than stable, particularly towards the end of its life.
2. The standard deviation of the sample is presented to indicate the consistency observed within a given chamber type. Larger deviations are associated with the 2MV results for two reasons: the air kerma rate was 0.1 Gy/min instead of (typically) 1.0 Gy/min, and variations in the Van de Graaff machine output made the measurement reproducibility somewhat worse than in ^{60}Co.
3. The chamber types NE 2561 and NE 2611 have been considered separately. Any difference between the two types is not significant at these qualities.
4. Most chambers have been calibrated more than once during this time, usually at three-yearly intervals or after repair. The means given here weight all chambers equally, independent of the number of calibrations performed.

6 Publications and Reports (June 1999 – March 2001)

DuSautoy, A., Roos, M., Svensson, H. and Andreo, P. (2000) Review of the validation of the data and methods recommended in the international Code of Practice IAEA TRS-381 (1997), in “Validation of the data and methods recommended in the international Code of Practice IAEA TRS-381 (1997)”, IAEA Tec-Doc 1173, IAEA, Vienna, 1-10

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McEwen, M. R., Williams, A. J. and DuSautoy, A. R. (2001) Determination of absorbed dose calibration factors for therapy level electron beam ionization chambers Phys. Med. Biol., 46, 1-15

Miller, A. and Sharpe, P. H. G. (2000) Dosimetry intercomparisons in European medical device sterilization plants. Radiat. Phys. Chem , 59, 323-327

Nutbrown, R. F. and Sander, T. (2000) “Corrections to air kerma rate measurements from a ^{192}Ir high dose rate brachytherapy source to free space conditions”. NPL Report CIRM 39. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

Nutbrown, R. F. and Shipley, D. R. (2000) “Calculation of factors to convert from air kerma to absorbed dose to water for medium energy photons”. NPL Report CIRM 41. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

Nutbrown, R. F. and Shipley, D. R. (2000) “Calculation of the response of a NE2561 ion chamber in a water phantom for high energy photons”. NPL Report CIRM 40. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

Nutbrown, R. F., Duane, S., Shipley, D. R. and Thomas, R. A. S. (2000) “Evaluation of factors to convert absorbed dose calibrations in graphite to water for mega-voltage photon beams”. NPL Report CIRM 37. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

Sharpe, P. H. G., Sephton, J. P. and Chu, R. D. (2000) Real Time Dosimetry Measurements at an Industrial Irradiation Plant. Radiat. Phys. Chem., 57, 687-690

Sharpe, P.H.G and Miller, A. (1999): “Guidelines for the calibration of dosimeters for use in radiation processing”. NPL Report CIRM 29. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

Williams, A. J. and Rosser, K. E. (1999) “Proceedings of NPL workshop on recent advances in calorimetric absorbed dose standards”. NPL Report CIRM 42. National Physical Laboratory, Teddington, TW11 0LW, United Kingdom.

TABLE 2. NPL Calibration Services in Photon and Electron Dosimetry

	Photon Standards					Electron Standards		Reference Dosimetry		
	Protection	Diagnostic	Therapy		Industrial	Therapy	Industrial	Fricke	Dichromate	Alanine
Beam Qualities	x-rays: 8 kV – 300 kV γ-rays: ^{241}Am, ^{137}Cs, ^{60}Co	x-rays: 25 - 150 kV	x-rays: 8 kV – 280 kV γ-rays: ^{60}Co	x-rays: 4 - 19 MV γ-rays: ^{60}Co	γ-rays: ^{60}Co	electrons: 3 - 19 MeV	electrons: 3 - 10 MeV	x-rays: > 2 MV ^{137}Cs, ^{60}Co e^- > 8 MeV	^{60}Co	x-rays: > 2 MV ^{137}Cs, ^{60}Co e^- > 1 MeV
Dose / Doserate	50 mGy/h	5 –50 mGy/h	0.1 Gy/min	1 Gy/min	0.2 kGy/min	1 Gy/min	< 20 kGy/min	30 - 100 Gy	2 - 55 kGy	5 Gy - 70 kGy
Primary Standards	ion chambers: 50 kV free air 300 kV free air ^{60}Co cavity	ion chambers: 50 kV free air 300 kV free air	ion chambers: 50 kV free air 300 kV free air ^{60}Co cavity	graphite photon calorimeter	graphite photon calorimeter	graphite electron calorimeter	graphite electron calorimeter	graphite photon calorimeter	graphite photon calorimeter	graphite photon calorimeter
Primary Quantity	air kerma	air kerma	air kerma	absorbed dose to graphite	absorbed dose to graphite	absorbed dose to graphite	absorbed dose to graphite	absorbed dose to graphite	absorbed dose to graphite	absorbed dose to graphite
Calibration Quantity	air kerma	air kerma	air kerma / exposure	absorbed dose to water	absorbed dose to water	absorbed dose to water	absorbed dose to water / silicon	absorbed dose to water	absorbed dose to water	absorbed dose to water