STANDARDISATION AND CALIBRATION FOR RADIATION PROTECTION PURPOSES IN THE UNITED KINGDOM

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PRIMARY STANDARDS AND CALIBRATION RADIATIONS, X-, GAMMA AND BETA RADIATIONS

Primary standards for the realisation of the quantity exposure were established at the NPL several decades ago. Free air chambers are used for X-rays generated at 300 kV and below and graphite cavity chambers for X-rays generated at 1 MV and 2 MV as bremsstrahlung spectra from a Van de Graaff accelerator. About 10 years ago a set of X-ray qualities was developed providing a series of X-ray spectra specifically to be used for the calibration of protection-level secondary standard ionisation chambers. These spectra generated between 10 kV and 280 kV have approximately the same spectral resolution and for a given tube current provide approximately the same exposure rate at the same distance from the X-ray tube foci. With the exception that the 1 MV and 2 MV qualities have been replaced by collimated caesium-137 and cobalt-60 beams, this range of radiation qualities has continued in use up to the present time. In the near future the ISO narrow spectrum series of X-ray radiations [1] will replace the NPL qualities over much of the energy range.

For beta radiations a parallel plate ionisation chamber was established as a primary standard, enabling the beta ray absorbed dose rate to air to be determined at fixed distances from radionuclide sources.

DISSEMINATION OF CALIBRATIONS

Since the introduction of the series of X-ray protection-level qualities, the aim has been to provide calibrated secondary standards to outside laboratories which would undertake the routine checking of area monitors. Eighteen centres in the UK now hold such secondary standards and, including recalibration work and calibrations for laboratories overseas (25 countries), a total of more than 100 secondary standard protection-level systems have been calibrated against primary standards. Thus within the UK the means has been supplied for the traceable calibration of all area monitors at the 14-monthly interval stipulated in our new Ionising Radiations Regulations 1985 [2] and for the calibration aspect of instrument type-testing.

Secondary standards for beta-radiations have been supplied in the form of radionuclide sources calibrated in terms of absorbed dose rate to air or to tissue at fixed distances using the primary standard described earlier. These sources correspond to the Series 1 sources listed in ISO 6980 [3]. Table I indicates the approximate dose rates available for the sources of highest activity supplied for each nuclide.

TABLE 1. NPL SECONDARY STANDARD BETA-RAY SOURCES

Nuclide	Calibration distance mm	Absorbed dose rate to tissue at 0.07 mm depth $mGy\ h^{-1}$
Sr-90+Y-90	300	14
Tl-204	300	2
Pm-147	200	1

PERSONAL DOSIMETRY

All the UK personal dosimetry services are subject to approval by the Health and Safety Executive (HSE), and for the purpose of ensuring that 'doses are assessed on the basis of accepted national standards', periodic intercomparisons are organised. In the case of services for the monitoring of external radiations, dosemeters are irradiated at a major secondary laboratory equipped with NPL standards and sent out to the services for measurement. The service run from the centre housing this secondary laboratory is directly audited by NPL, and other services may also be directly audited by NPL at the request of HSE. The calibration of dosemeters in some services may be based on the use of NPL calibrated secondary standards but the majority make use of radionuclide sources of certified activity. In either case the procedures ensure that all personal dosimetry relates back to national standards. A similar scheme, based on the assessment of tritium in water samples, has been initiated for the auditing of internal dosimetry services.

QUANTITIES AND UNITS

Following the change to SI units in ionising radiation metrology, the British Committee on Radiation Units and Measurements (BCRU) recommended the use of the quantity air kerma K_a for photon dosimetry in air [4]. According to the quantity in which the secondary standard is scaled, NPL provides calibrations in terms of exposure in röntgens or coulombs per kilogram, absorbed dose rate to air in rad h^{-1}, and air kerma (rate) in mGy(h^{-1}).

The BCRU gave interim recommendations [4] for the approximate conversion to 'dose-equivalent' of readings on protection instruments scaled in röntgens, viz. 1 mR = 10 µSv, pending expected guidance from ICRU on new dose equivalent quantities. Following the publication of ICRU 39 [5] and the recommendation that the new quantities ambient dose equivalent, H*(d), and directional dose equivalent, H'(d), be adopted for area monitoring within the UK, recommended conversion factors have been published by BCRU [6] as given by Wagner et al [7]. For X-ray calibration qualities in general use in secondary standardising laboratories, factors are becoming available for converting the air kerma calibrations supplied by NPL to the new dose equivalent quantities. Table II lists factors for the ISO narrow spectrum series of X-ray qualities based on the use of measured spectra folded in with the conversion relationships given for monoenergetic photons. Similar factors are available for use with the NPL protection-level X-ray qualities as long as they continue to be employed.

TABLE II. FACTORS FOR CONVERTING AIR KERMA TO AMBIENT AND DIRECTIONAL DOSE EQUIVALENT - ISO NARROW SPECTRUM FILTERED X-RADIATION SERIES

Generating voltage kV	Mean energy keV	Conversion factors	
		$H^*(10)/K_a$ (Sv/Gy)	$H'(0.07)/K_a$ (Sv/Gy)
40	33	1.18	1.27
60	48	1.59	1.49
80	65	1.73	1.60
100	83	1.71	1.60
120	100	1.65	1.55
150	118	1.58	1.50
200	161	1.46	1.39
250	205	1.39	1.34
300	248	1.35	1.32

For NPL beta-ray secondary standards calibrated in terms of absorbed dose to tissue at a depth of 0.07 mm in units of mGy h^{-1}, the corresponding directional dose equivalent rate has the same numerical value with units mSv h^{-1}.

STANDARDS FOR SURFACE CONTAMINATION AND ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS, AND FOR NEUTRON DOSIMETRY

To allow radionuclide surface contamination monitors to be calibrated regularly with reference to national standards, as required by regulations, NPL has developed a programme for the calibration of large area sources of α- and β-emitting radionuclides. The β-emitting nuclides include C-14, Pm-147, Tl-204, Cl-36 and Sr-90+Y-90 covering an energy range above 0.15 MeV, and the α-emitting nuclide is Am-241. These correspond to the Class 1 reference sources of ISO draft standard 8769 [8]: the calibration certificate gives the measured emission rate. The general requirements for Class 2 reference sources of the same radionuclides are the same as for Class 1 but these sources are calibrated against Class 1 sources using a reference transfer instrument. The requirement for such calibrated sources and for general agreement on methods for improving surface contamination monitoring capabilities has received support from a recent intercomparison of such measurements in UK hospitals [9].

Another requirement which has become evident recently is that for radionuclide solution standards in the 10-100 Bq/g range, in connection with studies of environmental activity. Such standards are now issued for an expanding range of pure and mixed radionuclides. A programme has started for the development of reference materials with agreed low levels of radionuclide content.

Traceability in the UK for radiation protection purposes for neutron radiations is achieved by providing access to standardised neutron fields at NPL, either source- or accelerator-based. These cover the energy range 1 keV to 20 MeV, the accelerator fields resulting from the use of proton and deuteron beams from a 3.5 MV Van de Graaff accelerator with a variety of targets. Neutron-sensitive devices of all types may be irradiated and precision long counters compared with the NPL standard precision long counter. Neutron dose equivalent values are calculated from the standardised neutron fluence rates by the use of internationally agreed conversion factors.

NATIONAL MEASUREMENT ACCREDITATION SERVICE (NAMAS)

NAMAS, which has its headquarters at NPL, is a Government Service under which about 600 laboratories to date are accredited for certain measurement activities, either of testing or calibration. Calibration laboratories fall within the British Calibration Service (BCS) section of NAMAS and a current aim is to have secondary level radiation protection laboratories accredited within this system and added to the list of about 200 laboratories accredited for calibration work in a variety of fields. The assessment of laboratories is performed against published criteria and a list of the technical criteria for the ionising radiation field is given in Table III (* undergoing revision, + in preparation). The revised documents draw heavily on the ISO standards referred to in earlier sections.

TABLE III. BCS RADIOLOGICAL CRITERIA - INSTRUMENT AND SOURCE CALIBRATION

Doc. No.	Supplementary Criteria for Laboratory Accreditation -
B0811*	Calibration of Radiological Protection Level Instruments: X-, Gamma and Beta- Rays
B0813*	Calibration of Radiological Protection Level Instruments: Neutrons
B0814	Calibration of Radionuclide Sources: Activity, Particle or Photon Emission Rate, Exposure Rate or Air Kerma Rate
B0815+	Calibration of Surface Contamination Monitors

In addition to the supplementary criteria, general criteria are set for laboratory organisation and staffing; importance is laid on written measurement procedures and substantiation of claimed uncertainties of measurement. The use of NPL calibrated secondary standards is a central requirement and we believe that accreditation in this field will be an important contribution towards improved quality assurance in radiation measurements of all types.

REFERENCES

[1] International Standards Organisation, ISO 4037 (1979).
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[3] International Standards Organisation, ISO 6980 (1984).
[4] BCRU, Brit.J. Radiol., 55, 375-377 (1982).
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[8] International Standards Organisation, ISO DIS 8769 (1986).
[9] WOODS M.J., Appl. Radiat. Isot., 38, 899-905 (1987).