# 1. Report on Radiation Protection Calibration Activities in Australia.

by

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## INTRODUCTION

Australia is a federation of eight autonomous States or Territories. Each of these is responsible for many matters including radiation safety within their borders. National matters are the responsibility of the Federal Government. The Australian Radiation Laboratory (ARL) is a part of the Federal Government Department of Human Services and Health and undertakes research and service activities related to radiation health. Work related to both ionising and non ionising radiation and regulatory matters is performed. Some of the research activities relate to radiation measurement standards, environmental radioactivity (e.g. radon in air, radioactivity in drinking water), effects of electro-magnetic fields on health (ELF), ultra violet radiation (UV) and laser safety, radiochemistry, medical applications of radiation (and doses to the population as a result), general health physics, thermoluminescent dosimetry (TLD) and electron spin resonance (ESR) dosimetry. The calibration of protection instruments are undertaken by the Ionising Radiation Standards Group within the Laboratory and by State Health Laboratories.

## NATIONAL RADIATION DOSIMETRY STANDARDS

For a measurement made in Australia to be legal it must be traceable as prescribed in the National Measurement Act. In particular, Section 10 requires that the measurement be made in terms of Australian units of measurement, traceable to the appropriate Australian standard.

The Australian standard of the quantity Exposure is maintained by ARL as an agent of the National Measurement Laboratory (NML) of the Commonwealth Scientific and Industrial Research Organization, Division of Applied Physics. The Standard is an absolute primary standard, maintained without reference to any other exposure standard. It is maintained by means of free air and cavity ionisation chambers in which a sensitive volume is precisely defined by design - the charge collected from the mass of air in this volume leads to a determination of the unit of the quantity exposure ($C.kg^{-1}$). The Laboratory also maintains working standards of absorbed dose. The primary standard for this quantity and for activity are maintained by the Australian Nuclear Science and Technology Organisation (ANSTO) under similar agent arrangements. However the majority of protection calibrations are performed tracable to the exposure (or related air kerma) standard using transfer ionisation chambers.

The design of the free air chamber for low energy X-rays has been outlined elsewhere[1, 2]. The free air chamber for use between 50 kV and 300 kV was designed using published information[3]. For $^{60}Co$ and $^{137}Cs$ gamma rays, ARL has a carbon cavity chamber similar to that described by Boutillon and Niatel of BIPM[4], and an aluminium cavity chamber based on the design of Kemp and Barber[5]. Factors to correct for various effects in these chambers have been determined at ARL.

The national standard of Absorbed Dose is maintained using a graphite calorimeter which provides absolute measurements of the absorbed dose to carbon at $^{60}Co$ and 6, 18 and 25 MV linear accelerator (linac) photon qualities[6, 7, 8]. Absorbed dose to water is obtained using a transfer procedure. ARL maintains a secondary standard therapy level dosemeter (Nuclear Enterprises NE2560/2561) which is calibrated against the national standard of absorbed dose to both carbon and water at the $^{60}Co$ quality[9], and offers dosemeter calibrations against this working standard in graphite and water phantoms. ARL also has a Domen type calorimeter and another smaller portable microcalorimeter under development[10]. When completed this will improve confidence in the present working standard dosemeter and will provide for calibrations at other qualities, possibly including $^{137}Cs$ gamma rays, 300 kV X-rays (and higher up to 450 kV) and linac photon and electron beams from 5 to 25 MV.

## RECENT STANDARDS INTERCOMPARISONS

ARL regularly participates in intercomparisons of exposure standards, mostly at dose levels higher than those usually applicable in radiation protection.

Section I of the Comité Consultatif pour les Étalons de Mesures des Rayonnements Ionisants (CCEMRI(I)) has recommended that national standards should be compared with those at BIPM at intervals not exceeding 10 years[11]. The ARL exposure standard for medium energy X-rays was last compared with the BIPM standard in April 1988 when the $^{60}$Co exposure standards were also compared[12].

ARL has participated in the IAEA postal thermoluminescent dosimetry (TLD) absorbed dose intercomparisons since 1971[13]. Results obtained by ARL are well within the 5% limits considered to indicate good agreement with the IAEA.

ARL has participated in several indirect environmental level dosimetry intercomparisons conducted by the Environmental Measurements Laboratory (EML) of the USA involving TLDs[14, 15]. The results of these intercomparisons have been within 5% providing appropriate corrections are made for fading and transit doses. From time to time problems have been experienced due to the correction for fading and due to our transit exposures being higher than those for most other countries. Exposures are typically 15 to 75 mR over a three month period, the larger ones being laboratory exposures while the smaller ones are usually field exposures. The Laboratory recently undertook a joint project with the EML to better understand the fading. In addition in 1982 the laboratory participated in an international protection level intercomparison which is outlined in the next section. The results were most satisfactory.

PROTECTION LEVEL CALIBRATION FACILITIES

ARL has calibration facilities at the protection level for X, gamma and beta radiations. These include the International Organization for Standardization (ISO) heavily filtered X-ray qualities[16]. At ARL the generating potential for these X-ray qualities is determined using a resistive divider in the high voltage generator oil-tank. The divider is checked by two external dividers with associated DVMs which are calibrated by the NML traceable to the Australian Standard Volt.

The laboratory possesses sealed radioactive sources of $^{137}$Cs, $^{60}$Co, $^{226}$Ra and $^{241}$Am - others having shorter half-lives are sometimes available. The exposure or absorbed dose produced by these sources is measured using transfer standard instruments traceable to the national exposure standard. The ion chambers used are produced by Nuclear Enterprises or Exradin.

ARL has purchased a standard beta ray calibration system from the National Physical Laboratory ( NPL) of the UK. The system comprises $^{90}$Sr/$^{90}$Y, $^{204}$Tl and $^{147}$Pm beta sources, together with beam flattening filters. It is used for survey meter calibrations.

Five large area sources (3 beta emitters and 2 alpha emitters) are also available for testing surface contamination meters. The sources are traceable to the Physikalisch-Technische Bundesanstalt (PTB) (Germany). There are not many requests for these calibrations and there is no overriding legal requirement for surface contamination monitors to be calibrated.

In recent years, with increasing State legislation and increasing use of ionising radiation in the community, the number of requests for protection level calibrations has increased. In response to this demand each state has been supplied with a standard calibration facility, thus a regional system has been developed to disseminate the exposure standard[17, 18]. Equipment supplied by ARL has been installed in all Australian capital cities (except Darwin, pending the availability of a suitable site) to enable State or Territory Health Departments to provide traceable calibrations.

Each facility includes a collimated source housing[16], an instrument support trolley and rails (Figure 3). A set of $^{137}$Cs sources is provided with each facility (Table 3). A calibrated 100 ml ionisation chamber (Exradin model A5) and electrometer (Keithley model 35617) for use in X-ray beams are also supplied. The ability to perform X-ray calibrations depends on access to suitable generators. One State has duplicated some of the ISO qualities. In addition to the facilities provided to them by the laboratory many of the State Health Laboratories have similar additional sources. In most cases the accuracy of either their activity or their air kerma rates are not well known in a manner traceable to the Australian standard.

The prototype facility was used in an international air kerma intercomparison[19] involving fourteen major primary standards laboratories. It was intended that each participant expose LiF TLDs to an air kerma of 0.3 mGy at a rate of 50 $\mu$Gy.h$^{-1}$, and to 0.3 to 1.0 mGy at a freely chosen rate. The results obtained by ARL were within 1% of the overall mean value. It is therefore reasonable to expect that the calibration facilities installed in the States are capable of similar results.

## PRMS TRACEABILITY AND CALIBRATIONS

The laboratory uses a commercial (Teledyne) based fully automatic TLD personal monitoring system. The custom designed badge cases incorporate four filtered areas (an unfiltered area, 845 mg. cm$^{-2}$ plastic, 0.25 mm Cu + 2.8 mm Al and 2.7 mm Cu + 0.5 mm Al) and use a CaSO4-.Dy phosphor in a teflon matrix as the sensitive element. The dosemeters (TLD plus badge case) are calibrated by exposing them on a perspex block phantom similar to the IAEA standard water phantom. They are used to assess the personal dose equivalent. They are exposed to a range of qualities covering the energy range from 10 kV up to $^{60}$Co and referenced to standards exposed to 2 mSv from $^{137}$Cs. Similar quality assurance standards are used throughout each batch of approximately 400 dosemeters assessed. Regular weekly tests of the automatic TLD readout machines are performed to check their stability while second readouts are performed on the TLD cards to check the efficiency of the readout system. The relationship between the various energy radiations and the standards is re-evaluated every five years. The TLD cards are automatically read out in all four areas and the effective dose to which they have been exposed is derived using an algorithm. The majority of monitors are issued for wearing over 4, 8 or 12 week periods with most being for 12 weeks.

Other smaller services are operated in Australia by the Queensland Health Department, ANSTO and the Western Australian Health Department. The Laboratory, which monitors 25,000 of the 35,000 radiation workers in Australia, is developing a data base on the cumulative doses of all radiation workers in Australia.

## CALIBRATION FACILITIES FOR NEUTRONS.

A neutron calibration facility has been established at the Laboratory in a room 8 m x 10 m x 6 m. A calibration rail allows the source and the instrument to be calibrated to be located at the centre of the room. This results in minimum scatter. Exposures and measurements can be performed using the shadow cone method, the semi-empirical method where data is fitted to a universally accepted equation and by the polynomial method where data is fitted to an arbitrary polynomial.

A full set of 10 Bonner spheres ranging in diameter from 3 inches to 12 inches are available. These incorporate a $^{3}$He detector and a full set of shadow cones exist for them. In addition, two $BF_3$ detectors in 3 inch and 9 inch spheres which incorporate cadmium shields are also available. At present $^{241}$Am/Be sources are used, the absolute emission strength of one of them has been determined using the NPL manganese sulphate bath. It is planned to acquire a $^{252}$Cf source in the near future. The facility has been designed so that the shadow cones and instruments can be moved in the x, y and z directions and rotated through 360 degrees. A Monte Carlo neutron transport program (MCNP4A) is also used to support these facilities.

## CALIBRATION PROBLEMS AND EXPERIENCES

At one stage when calibrating a large volume chamber in terms of Dose Equivalent for one of the harder ISO qualities, problems were encountered due to non uniformity of the radiation field. This occurred when a 1 L chamber was being compared to the 100 ml chamber which was used as the local reference instrument.

## EMERGENCY PREPAREDNESS

The laboratory has several sets of instruments which are kept in case they are needed for emergency monitoring. These instruments include thick and thin sodium iodide detectors, a range of GM and ionisation chamber instruments. The calibration of these instruments is traceable to the protection calibration facilities outlined above.

## USE OF THE ICRU NEW OPERATIONAL QUANTITIES

Use of these is recommended in Australia by the National Health and Medical Research Council for limiting occupational exposure to ionising radiation. However, in terms of instrument calibration, unless specifically requested by a client, an instrument is usually calibrated in terms of the quantity and units in which it is scaled.

When the new operational quantities are required they are derived from the exposure standard by using the conversion coefficients recommended by the ICRU in its Report 47.

## OTHER MATTERS RELATED TO CALIBRATION

From a regulatory viewpoint the Laboratory provides the secretariat and much input to the Radiation Health Advisory Committee (RHC), which is a committee of the National Health and Medical Research Council. The RHC produces many "Codes of Practice" for matters related to radiation protection. While instrument calibration is not specifically covered by the series, many useful matters related to radiation protection are covered.

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