Progress in Neutron Metrology at NPL, London, UK

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1. Introduction

The National Physical Laboratory (NPL), situated in London near Heathrow Airport, is the UK's national standards laboratory for many different types of measurement, including those associated with radiation protection. The Neutron Metrology Group runs services for calibrating and characterising neutron instruments to high precision, and also has a research programme for improving the quality and usefulness of neutron measurements.

This presentation describes some recent developments in neutron metrology and dosimetry at NPL.

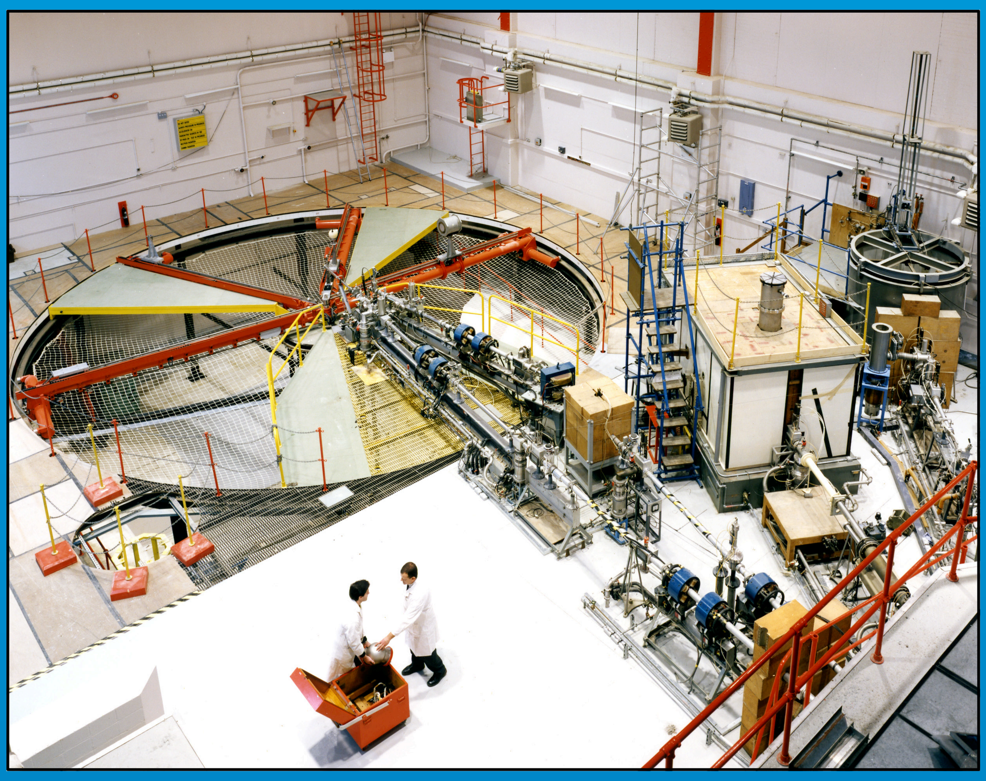

Figure 1: The main experimental area, measuring approximately 18 × 18 × 26 m. A Van de Graaff accelerator behind the shield wall (lower right) provides ion beams for neutron production in the low-scatter area (centre left) or the thermal pile (centre right). Alternatively, radionuclide neutron sources may be mounted at the centre of the low-scatter area.

2. Fast neutron fields

Figure 1 shows the main experimental area in the neutron building at NPL. To produce monoenergetic neutrons, ion beams from a 3.5 MV Van de Graaff accelerator behind the shield wall at the bottom right of the picture are directed on to a neutron-producing target at the centre of the low-scatter area (centre left). This target is at least 6 m from any massive structure. The neutron energy depends on the nature of the production reaction, the energy of the beam, and the angle at which the test object is mounted relative to the ion beam direction. Following recent work, the range of neutron energies that can be produced now extends from 8 keV to 17 MeV (although some energy regions within this range are not accessible). The neutron fluence delivered to the test item is measured using long counters (Figure 2), with a typical precision of 2 – 4%. The ion beam from the Van de Graaff may be pulsed for time-of-flight work.

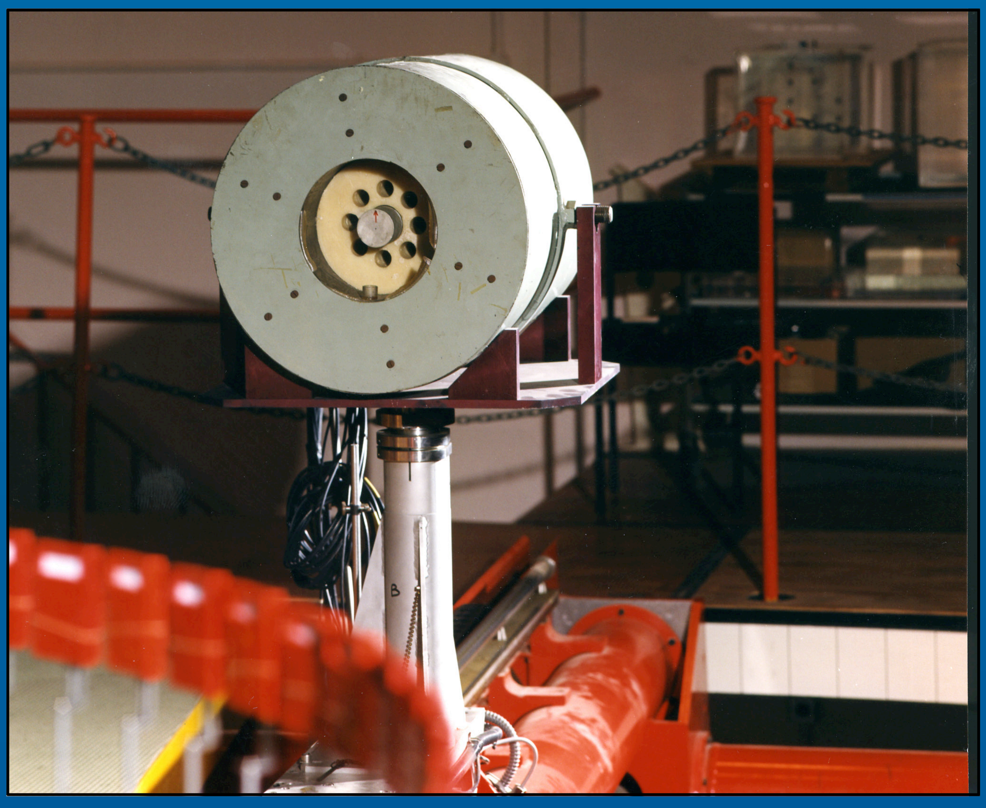

Figure 2: An NPL standard long counter. The long counters used for neutron fluence measurement have been calibrated using radionuclide sources with precisely known output (see Section 4), in conjunction with accelerator-based techniques and with Monte Carlo modelling. Ambient and personal dose equivalent values are deduced from the measured fluences using internationally accepted conversion coefficients.

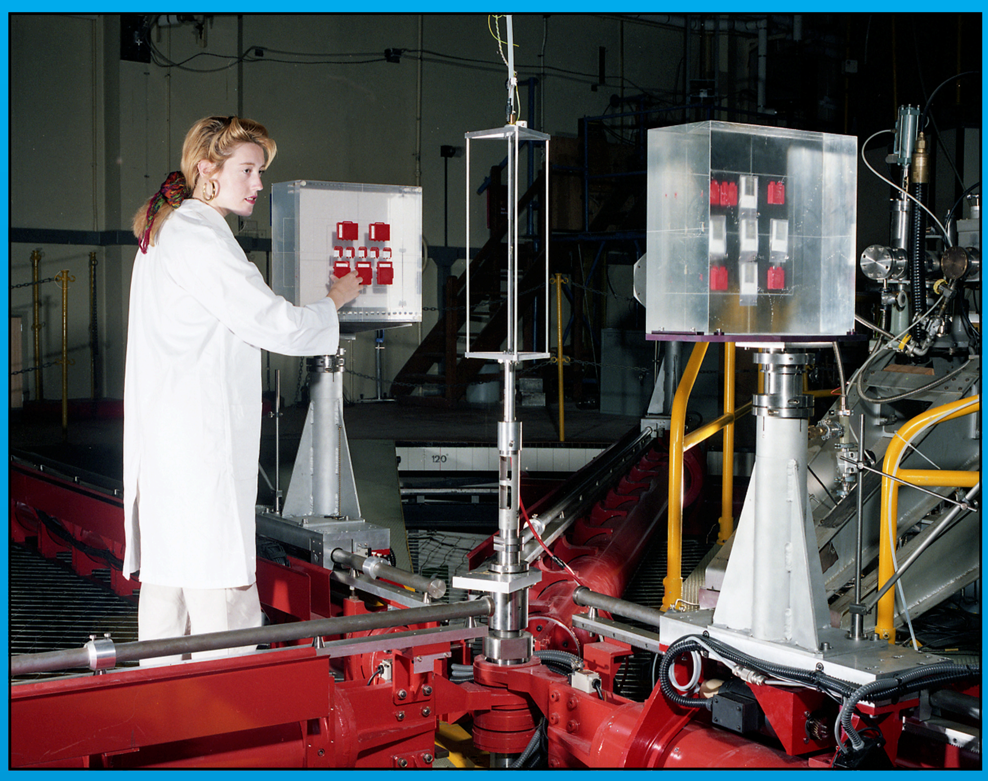

Figure 3: The pneumatic transfer system for the high-output ^{252}Cf source (3.3×10^8 neutrons per second into 4π, calculated for 31st May 2012).

As an alternative to monoenergetic neutrons, well-characterised broad-spectrum fields (including simulated workplace fields) may be produced by substituting a thick target or by removing the final section of beam line completely and mounting a radionuclide source instead. NPL has a range of such sources, including at present a particularly high-output ^{252}Cf source that produces 3.3×10^8 neutrons per second into 4π, corresponding to a personal dose equivalent rate of 3.8 mSv h^{-1} at 1 m. A pneumatic transfer system (Figure 3) has recently been installed to bring this source to the irradiation position remotely.

The detector mounting supports, visible in the upper left of Figure 1 as orange-red tubular structures, are motorised and have now been placed under the control of a LabVIEW computer program. This allows the detector position to be changed automatically during data acquisition.

3. Thermal neutron fields

Figure 1 also shows the NPL Thermal Pile (centre right). This comprises a large graphite moderator containing two beryllium targets that produce neutrons copiously when irradiated with deuterons from the accelerator. A servo system maintains the level and spatial uniformity of the neutron output. Small artefacts can be irradiated in isotropic fields of up to approximately 1.2×10^7 neutrons cm^{-2} s^{-1} at the centre of the pile, while larger objects (including standard phantoms) may be placed in a beam of up to 4×10^4 neutrons cm^{-2} s^{-1} that is extracted vertically. Fluences are measured by activation of gold foils with and without cadmium covers.

Following enlargement of the central cavity access hole to a diameter of 120 mm, the testing of certain types of reactor monitoring instrument can now be carried out in this facility.

4. Measurements of radionuclide source output

NPL has one of only a few facilities in the world capable measuring the neutron output rate from sealed radionuclide sources to high precision (1 – 2%). The facility was recently moved to a new location on the NPL site and extensively modernised.

The source under test is placed inside a small stainless steel sphere and transferred under remote control into a 1 m diameter bath of manganese sulphate solution (Figure 4). The neutrons activate the manganese, and this activity is measured by pumping the solution past sodium iodide gamma detectors in an adjacent room. The output rate of the source can then be calculated.

Figure 4: The manganese bath (large tank right of centre) is used to measure the output rate of sealed radionuclide neutron sources to high precision. The source is mounted in a small stainless steel sphere, which is then evacuated and transferred by a pre-programmed transport system to the centre of the bath.

The operation of taking the source out of its shielded transit container and placing it in the sphere is carried out in the source handling cell (Figure 5). This has thick shield walls and is fitted with remote manipulators and closed circuit TV. In addition to its role in the manganese bath facility, it is also well suited for inspecting, testing and servicing sealed neutron sources.

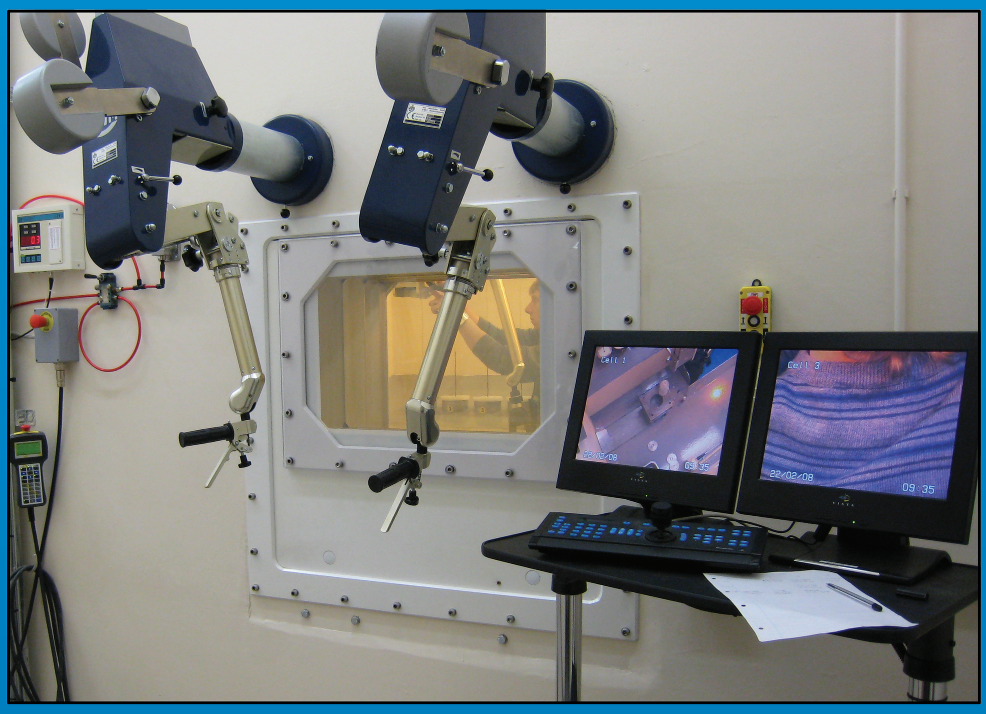

Figure 5: Source handling for the manganese bath facility is carried out inside a shielded cell equipped with manipulators and TV cameras. The cell is also suitable for general testing, inspection and servicing of sealed neutron sources.

5. Research programme

A programme of research is carried out in order to keep NPL's neutron metrology relevant to how neutrons are used in the UK, and up-to-date with modern technologies. One current project is to produce a Bonner sphere spectrometer with a raised upper energy limit (currently about 20 MeV for conventional polyethylene spheres) for use at high energy facilities. Metal shells within the spheres can provide a high energy response via (n, 2n) reactions, and Monte Carlo calculations have shown that tungsten is particularly effective. Furthermore the shell can be close to the centre of the sphere, minimising the weight, although a new set of spheres with enlarged central cavities will have to be constructed.

6. Acknowledgement

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