

# Developments of Neutron Metrology at CIAE

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The neutron metrology has been developing since 1981. A series of facilities were established and operated in various neutron fields that were generated by radionuclide sources, accelerators and reactors. Hitherto, we have had some abilities on neutron measurements such as intensity of neutron source, neutron spectra, neutron fluence and neutron dose. But our work is still at the beginning phase, therefore, a great deal of work needs to be studied, researched and developed. At present, we had possessed some instruments that include manganese bath system for measuring the emission rate of neutron sources,  $^{235}\text{U}$  ionization chamber for measuring the fluence of thermal neutron, Bonner Sphere Spectrometer (BSS), tissue equivalent ionization chamber for measuring neutron doses and a set of instruments for measuring the fluence of monoenergetic neutrons and so on. Some main work that is doing and is about to do is mentioned in the following.

## 1. Monoenergetic fast neutrons reference radiation fields.

In 1996, our division introduced a 5SDH-2 pelletron accelerator from National Electrostatics Corporation of the United States. The terminal voltage of the accelerator is 1.7MV. The accelerator is located in a  $15\text{m}\times 10\text{m}\times 10\text{m}$  of hall. A grid is built on the position of 1.5m from the ground of the hall for reducing the scattering. A circular track of 2.5m in radius and three radial tracks are set up on the grid. The monoenergetic neutrons from 0.1MeV to 19MeV can be obtained by reactions as  $^7\text{Li}(p,n)^7\text{Be}$ ,  $\text{D}(d,n)^3\text{He}$  and  $\text{T}(d,n)^4\text{He}$  by the accelerator. Meanwhile, some primary standard detectors have been developed gradually for the neutrons fluence measurements. They include the recoil proton proportional counter for the 0.1MeV—1.5MeV neutrons, the semiconductor telescope for 1.5MeV—5.5MeV neutrons, the CsI scintillation telescope for 6.0MeV—19MeV neutrons. In addition, the associated-particle methods for  $\text{D}(d,p)\text{T}$  and  $\text{T}(d,n)^4\text{He}$  are also used for detecting 2.5MeV and 14.8MeV neutrons fluence. The long counter as secondary standard detector is calibrating for its efficiency, and has been finished at 144keV, 250keV, 565keV, 2.8MeV and 14.8MeV. Subsequently, the neutron spectra by target scattering will be calculated by Monte-Carlo code. Meanwhile, we are also doing the research about determining the efficient center of the long counter, etc. .

## 2. Establishment of 6—7MeV $\gamma$ rays reference radiation fields.

6—7MeV  $\gamma$  rays were obtained by the reaction of  $^{19}\text{F}(p,\alpha\gamma)^{16}\text{O}$  at our accelerator. Meanwhile, we calibrated the efficiency of HPGe detector by associated-particle method when the energy of the projectile proton is 340.5 keV.

## 3. Daily work for calibrations and verifications.

### (1) Measurements of the emission rate of radionuclide neutron sources.

The manganese bath instrument for measuring the emission rate of radionuclide neutron sources were established in 1982. Its efficiency was calibrated carefully by absolute method of  $4\pi\beta$ - $\gamma$  coincidence, and all the corrected factors were calculated by M-C code. The standard combined uncertainty is better than 1.0% for  $^{252}\text{Cf}$  neutron source. In general, 5—10 neutron sources are calibrated each year.

### (2) Calibrations of neutron dosimeters.

A  $8\text{m}\times 6\text{m}\times 6\text{m}$  of hall was built as the room of neutron dosimeter calibration. The standard neutron source is  $^{241}\text{Am}$ -Be source of which intensity is  $7.3\times 10^6/\text{s}$ , and it is calibrated by manganese bath method every year for two times. In general, we can calibrate or verify 10—30 neutron dosimeters each year.

## 4. Some plans.

(1)Improve on the 5SDH-2 accelerator to make it to be able to operate on pulse mode so as to get pulse neutron sources. Now we are drawing up the plan and applying for financial support.

(2)Develop the measuring technology of quasi-monoenergetic neutron spectra such as time of flight method, etc..

The thermal neutron spectrum was measured by time of flight method at the heavy water reactor of CIAE in 1995. The result shows a obvious deviation from the typical Maxwell distribution due to insert a 50cm long single crystal silicon in the thermal column of reactor. However, the measuring technology of quasi-monoenergetic neutron spectra is very different from that of thermal neutron spectrum. With the late beginning of introducing the accelerator into our laboratory, the work hasn't been carried out at our division. To measure the neutron fluence much more accurately, the work shall be very necessary.

(3)Re-establish thermal neutron reference radiation field and filter neutron field at the new reactor.

In 1980<sup>th</sup> and 1990<sup>th</sup>, we had established thermal neutron reference radiation field and filter neutron field at the swimming pool reactor and the heavy water reactor of CIAE. But both of these reactors will quit in the future several years. Therefore, we intend to re-establish the two fields at CARR( China Advanced Research Reactor) that will run in 2006. By different materials and equipment, we can obtain different energetic standard neutron reference radiation fields as thermal neutron, 186eV neutron, 2keV neutron, 24.5keV neutron and 144keV neutron, etc.

(4) Research of  $^{45}\text{Sc}(p,n)^{45}\text{Ti}$  reaction at the accelerator.

(5) Develop at CARR the simulation of realistic neutron spectra at workplaces.

As radiation metrology division, providing accurate calibration for neutron dosimeters is a very important thing. Therefore, we are meant to construct a set-up to replicate at CARR realistic neutron spectra encountered in practice at workplaces.

(6)Continue to perfect our Bonner Sphere Spectrometer (BSS).

We had gotten a lot of help from PTB on the unfolding of BSS. But the response functions of BBS must be calculated by ourselves because the density of the used polythene is different from theirs.

(7)Research of Tissue Equivalent Proportional Counter (TEPC).

TEPC had been developed for some years in many countries and obtained very good results for the measurements of neutron doses. We also will develop its research so that enrich our measuremental methods of neutron doses.

In a word, we will continue to improve gradually our technology and our facilities in order to enhance our abilities on neutron measurements, and to attend more intercomparisons.