Recent Activities of the neutron standardization at KRISS

Neutron Spectrometry with BSS

KRISS Bonner sphere system

KRISS constructed the multi-sphere system for the neutron spectrometry (Bonner Sphere spectrometer), manufactured by Centronic Ltd., UK. The spheres are made of high density polyethylene and He-3 proportional counter (SP9 from Centronic Ltd., UK) is used as a thermal neutron detector.

The Bonner Sphere set has 10 spheres of 3", 3.5", 4", 4.5", 5", 6", 7", 9", 10", and 12" diameter and originally designed by PTB, Braunschweig.(1) The response matrix is calculated by the small modification of original PTB BS's response matrix, considering the difference of the density and the size of the spheres. The normalization of the response matrix is determined by the measurement of the neutron spectrum of ^{252}Cf source.

Neutron Spectrum Measurement of standard neutron sources at KRISS calibration room

The neutron spectra at KRISS calibration room were measured for ^{252}Cf, D_2O-moderated ^{252}Cf, and H_2O-moderated ^{252}Cf sources. Spectrum unfolding was performed with the MAXED package.(2)

Figure 2 shows the spectra of the bare ^{252}Cf source. For the bare ^{252}Cf source, the total and in-scattered neutrons were measured separately using the shadow cone technique, 150 cm from the source. The direct components from the ^{252}Cf source were obtained from the difference between the total and in-scattered neutron spectra. The deduced direct components were compared with the evaluated ^{252}Cf spectrum.(3) The energy spectra of the D_2O-moderated ^{252}Cf source were measured at four different positions: 50 cm, 100 cm, 150 cm, and 200 cm distance from the source. The spectra show that the thermal neutron components for four different measurements were almost the same, indicating that the thermal neutrons are due to the scattering inside the room. This is consistent with the fact that the thermal neutrons could not originate from the source because of the cadmium cover of the D_2O moderator. This means that the measurements were reasonably carried out for this source. For all four cases, the measurements and the calculations were found to correlate.

Comparisons of the calculated spectra with the measured values showed reasonably good agreement not only for the direct components but also for the in-scattered components. This indicates that the irradiation room at KRISS was correctly calibrated.

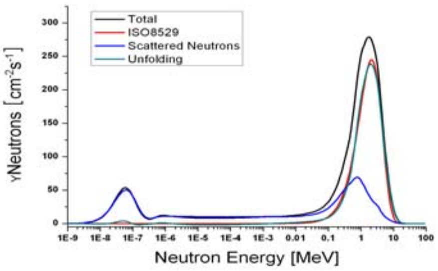

Figure 2 Neutron energy spectra from the bare and D_2O-moderated ^{252}Cf sources. The “total” and “in-scattered” neutrons are measured separately with the shadow cone method.

Neutron Spectrum Measurement at Nuclear Power Plant (PHWR)

With BSS system, we performed the measurement of the neutron energy spectrum at the workplace of Wolsong nuclear power plant in Korea. The reactor type is PHWR(Pressurized Heavy Water Reactor). The 10 points at the 4th and 5th floor of the reactor building were selected for the spectrum measurement, where the radiation workers access for the ordinary check of the operation. The single point measurement takes about 4 hours. For the comparison, we measured the neutron dose with neutron survey meter(EG&G Ortec, LB6411) and TLD with ISO water phantom. Figure 3 shows the measured energy spectra, which are the combined spectrum of original fission spectrum, scattered fast neutrons and thermal neutrons. The MAXED package was used for the unfolding and the WinBUGS[4] was used for the estimation of default spectra of unfolding procedure.

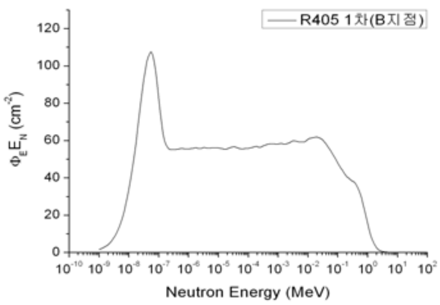

Figure 3 The typical neutron energy spectra measured at the Wolsong Nuclear Power Plant in Korea.

Neutron Spectrum Measurement of Neutrons from the nuclear reaction produced at 50 MeV cyclotron

The neutron energy spectra produced from the nuclear reactions of protons on ^{18}O target and protons on Copper target were measured with Bonner Sphere system. For the case of protons on ^{18}O target, the shadow cone method was used to extract the in-scatter neutron component.

(1) B. Wiegel, A.V. Alevra, "NEMUS- the PTB Neutron Multisphere Spectrometer: Bonner spheres and more ", Nucl. Instrum. Meth. A447, pp 36-41, 2002.

(2) Marcel Reginatto, Paul Goldhagen, Sonja Neumann, "Spectrum unfolding, sensitivity analysis and propagation of uncertainties with the maximum entropy deconvolution code MAXED", Nucl. Instrum. Meth. A476, pp 242-246, 2002.

(3) ISO 8529-1, Reference neutron radiations – Characteristics and methods of production, 2001.

(4) www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.html

Plans

1. **Extension of BSS**

   We plan to extend the measurement range of KRISS BSS up to ~200MeV.

   In 2007, the extended Bonner Spheres with Copper, Lead, and Iron ball will be produced. The calibration will be performed with ^{241}Am-Be source and also accelerator.

2. **Neutron Spectrometry with LSC(Liquid Scintillation Counter)**

   Because the energy resolution of BSS is very much limited, we are preparing LSC (liquid scintillation counter) system for the high resolution neutron spectrometry. In 2007, we will start calibration measurement with ^{252}Cf source and white neutrons from the accelerator. The gain stabilization system developed by PTB would be used if PTB provides.

3. **Neutron fluence with Long Counter**

   We are now preparing Long counter system, which should be well understood and calibrated. This will be used for the calibration of neutron irradiation system. Many neutron irradiators are not able to calibrate with the neutron emission rate of the source because the separation of the source is impossible.

4. **Improvement of survey meter calibration**

   As NPL has already reported,(5) the difference in the energy spectrum between the calibration field and the workplace field should be considered properly for the evaluation of a calibration constant and/or its uncertainty. We would like to study how we could apply this to our case, where we don't have limited number of energy spectra of Korean nuclear power plant.

(5) Maurice Cox, Peter Harris, Gyeonghee Nam, and David Thomas, "The use of a Monte Carlo method for uncertainty calculation, with an application to the measurement of neutron ambient dose equivalent rate", Rad. Prot. Dosimetry 121, pp 12-23, 2006.

International Comparison

- the comparison of emission rate, CCRI(III)-K9.AmBe.
- the comparison of neutron survey meter calibrations, EUROMET.RI(III)-S1.

The 2nd round Peer Review from 13 June 13 to 15

Period : June 13 to June 15, 2007

Reviewer :

Milos Kralik (Czech Metrology Institute) for neutron and dosimetry standards

Y. Hino (NMIJ) for Radioactivity Stantards

Reorganization of KRISS

- Operating Units of KRISS become 3 Divisions for R&D & 2 Divisions for Services, which was 4 Divisions & 2 Centers.
- Ionizing Radiation group was disappeared from the official chart of the organization.
- Dosimetry and Neutron standard belong to "Health Metrology Group" of "Division of Metrology for Quality Life".
- Radioactivity standards belongs to "Environment and Food metrology Group" of "Division of Metrology for Quality Life".

Staff Members

Three research scientists are fully involved for the neutron standardization.

- Hyeonseo Park, Ph.D in Nuclear Physics
- Jung Ho Kim, Ph.D in Nuclear Physics
- Kil-oung Choi, Master in Chemistry

Facilities

- **Radioactive neutron sources**

  two ^{252}Cf source : the emission rates of 2.05x10^{8} n/s and 1.95 x 10^{6} n/s

  two ^{241}Am-Be source : the emission rate of 1.229x10^{7} n/s and 2.325x10^{5} n/s
- **Low background neutron irradiation room** : size of 6.7x7.6x6.4 m^{3}
- **Manganese Sulphate Bath system for neutron emission rate measurement**
- **Bonner sphere system with 10 PE spheres**
- **Neutron detectors**

  Long counter with one He-3 proportional counter and one BF_3 proportional counter

  two REM counter(EG&G Ortec LB123),

  two H_2 proportional counter

  Liquid scintillation detector(BC501a)

  two BF_3 proportional counter

Publications and Communications

- **International**

- "Development of low-background CsI(Tl) crystals for WIMP search", H.S.Lee,H.Bhang,I.S.Hahn,M.J.Hwang,H.J.Kim,S.C.Kim,S.K.Kim,S.Y.Kim,T.Y.Kim,Y.D.Kim,J.W.Kwak,Y.J.Kwon,J.Lee,J.I.Lee,M.J.Lee,J.Li,S.S.Myung,H.Park,J.J.Zhu, Nucl. Instrum. Meth. A571, pp644-650, 2007.
- "Neutron calibration facility with radioactive neutron sources at KRISS", H. Park, J.H. Kim, K.O. Choi, *Tenth Symposium on Neutron Dosimetry (NEUDOS10)*, June 12-16, 2006, Uppsala, Sweden.
- "First limit on WIMP cross section with low background CsI(Tl) crystal detector", H.S.Lee,H.Bhang,J.H.Choi,I.S.Hahn,D.He,M.J.Hwang,H.J.Kim,S.C.Kim,S.K.Kim,S.Y.Kim,T.Y.Kim,Y.D.Kim,J.W.Kwak,Y.J.Kwon,J.Lee,J.H.Lee,J.I.Lee,M.J.Lee,J.Li,S.S.Myung,H.Park,H.Y.Yang,J.J.Zhu, Phys. Lett. B 633, pp201-208, 2006.
- "Development of a Respirator to Protection against Gaseous Tritium used for a

Pressurized Heavy Water Reactor and Evaluation of its Performance”, K.-O.Choi, H.Park,H.G.Kim, *Canadian Radiation Protection Association and Campus Radiation Safety Officers Conference 2005*, Canada, 2005.

- “The Measurement of Neutron spectral fluence with Bonner Sphere spectrometer for the dosimetric purpose”, H.Park, J.H.Kim, K.-O. Choi, *Proceedings of Inernational symposium on radiation safety management,* November 2-4, 2005, Daejeon, Korea.
- “Monte Carlo calculation of the efficiency calibration curve for a HPGE detector”, K.H.Ahn, J.K.Chun, J.M.Lee, K.B.Kee, H.Park, C.Y.Lee, *NMIJ-BIPM Workshop on the impact of Information Technology in Metrology,* May 16,18-20, 2005, Tsukuba, Japan.
- “Inhibition of ^{137}Cs contamination in cesium iodide”, Y.D.Kim, I.S.Hahn, M.J.Hwang, LiJin, W.G.Kang, H.J.Kim, S.C.Kim, S.K.Kim, T.Y.Kim, J.W.Kwak, Y.J.Kwon, E.K.Lee, H.S.Lee, J.I.Lee, M.J.Lee, S.S.Myung, H.Park, A.Schiedt, H.Y.Yang, J.J.Zhu, Nucl. Instrum. Meth. A552, pp456-462, 2005.
- “Absolute Measurement of the Neutron Emission Rate with a Manganese Sulphate Bath System”, H.Park, K.-O.Choi, J.M.Lee, K.B.Lee, M.S.Hahn, M.Kralik, Jour. Korean Phys. Soc., 47, pp603-609, 2005.
- “Activation Cross Section Measurements of 16O(n,3He)14C and 16O(n,t)14N above neutron Thrsholds up to 18.1 MeV”, J.H.Park, C.S.Lee, Y.K.Kwon, J.H.Lee, J.Y.Kim, K.B.Lee, H.Park, Jour. Korean Phys. Soc., 47, pp23-27, 2005.
- “A Monte-Carlo Intranuclear Cascade Calculation for the Propagation of Energetic Nucleons in the Nucleus”, M.J.Kim, H.Bhang, J.H.Kim, Y.D.Kim, H.Park, J.Chang, Jour. Korean Phys. Soc., 46, pp805-812, 2005.

- **Domestic**

- “Standardization of Mn-56 for the Neutron Emission Rate Standardization”, J.M.Lee, J.S.Seo, K.B.Lee, T.S.Park, H.Park, Bulletin of Korean Physical Society, 23/1, p301, 2005.
- “Neutron Response Function of H2 Filled Sperical Proportional counter”, H. Park, Bulletin of the Korean Physical Society, 23/2, p475, 2005.
- “Neutron Spectrometry with Bonner sphere system at nuclear power plant”, J.H.Kim, H.Park, K.-O.Choi, Bulletin of the Korean Physical Society, 23/2, p404, 2005