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Experimental Measurement of Neutron Flux Distribution Inside The Water-Filled Howitzer Using Isotope Sources In The Nuclear Research Institute, Vietnam

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Abstract: **-** The water-filled Howitzer had been studied and made in the Nuclear Research Institute (Dalat). It has been the specialized system with multi-function and the unique in Vietnam, that has been used to study experimentally characteristics of neutron in water medium, neutron flux distribution and dose-rate, neutron activation analysis using isotope sources. This report presents the first researches on experimental measurements of neutron flux distributions for sources of ^{252}Cf and ^{241}Am-Be (according to horisontal-radius direction) by the technique of neutron activation analysis using the standard foils of gold with cadmium covers and without ones. The experimental results were shown that thermal and epi-thermal neutron fluxes decreased gradually with distances from the source center. This study has been very useful for trainees carrying out measurements of neutron flux distributions and other characteristics using isotope sources.

Keywords: *Water-filled Howitzer, neutron flux distribution, neutron activation analysis.*

I. INTRODUCTION

Isotope neutron sources have widely used in the fields of industry (such as cement factory), construction (such as measurement of road humidity), research and training (such as neutron activation analysis, characteristics of neutron in slowing-down medium, neutron dose). Although neutron flux is not high, isotope neutron sources are still effective means for many research institutions without nuclear reactors or neutron generators. Therefore, the large-size water-filled Howitzer using isotope neutron sources of ^{252}Cf and ^{241}Am-Be was studied and made at the Nuclear Research Institute [1]. This Howitzer has multi-function and it is used to measure slowing-down and diffusion characteristics of neutron in the water medium (such as slowing-down and diffusion lengths, migration area), neutron activation analysis and dosimetry. In order to use this system, the first importantly work is survey thermal neutron fluxes depending on distances (in direction of horisontal radius) from the source center by activation analysis for gold foils without cadmium covers and with cadmium ones. Then, gamma spectrums for the foils are measued by the gamma spectrometer using HPGe detector. From that, thermal neutron fluxes depending on the horisontal distances from the source center are determined [1, 2, 5]. The expermental data are very important for selecting a position with the highest value of thermal neutron flux in order to activate samples applied in determining contents of elements.

II. THEORETIC BASIS OF DETERMINING NEUTRON FLUX

Specific counting rate (or specific activity) of A_{sp} is defined as [1, 2]:

$$A_{sp} = \frac{N_p / t_d}{SDCw} \quad (1)$$

Where N_p is gamma peak area (count) of interest; $S = 1 - e^{-\lambda t_c}$ is saturation coefficient corrected to irradiated time (t_c is irradiated time; $\lambda = \frac{\ln 2}{T_{1/2}}$; $T_{1/2}$ is half-life); $D = e^{-\lambda t_r}$ is delayed coefficient corrected to delayed time (t_r is delayed time); $C = \frac{1 - e^{-\lambda t_d}}{\lambda t_d}$ is measuring coefficient corrected to measured time (t_d is measured time); w(g) is irradiated sample mass.

When irradiation without cadmium cover (bare foil), specific activity of A_{sp}(bare) is:

$$A_{sp}(\text{bare}) = \frac{N_p / t_d}{SDCw} \quad (2)$$

When irradiation with cadmium cover (foil with cadmium cover), specific activity of A_{sp}(Cd) is:

$$A_{sp}(Cd) = \frac{N_p / t_d}{SDCw} \quad (3)$$

So, epi-thermal neutron flux will be:

$$\Phi_{epi} = \frac{A_{sp}(Cd)}{G_{epi}.I_0(\alpha).N_A.\theta.\gamma.\varepsilon_p / M} \quad (4)$$

And thermal neutron flux will be:

$$\Phi_{th} = \frac{G_{epi}}{G_{th}}(R_{Cd} - 1)Q_0\Phi_{epi} \quad (5)$$

Where Φ_{th} and Φ_{epi} ($n.cm^{-2}s^{-1}$) are thermal and epi-thermal neutron fluxes, respectively; $\sigma_0(cm^2)$ is capture cross-section for thermal neutron of interest; G_{th} and G_{epi} are self-shielding coefficients for thermal and epi-thermal neutrons, respectively (in fact, thin foils of gold are usualy used, $G_{th} \approx G_{epi} = 1$); $I_0(\alpha) = \int_0^\infty \frac{\sigma(E)dE}{E^{1+\alpha}}(1eV)^\alpha$ is resonant interal for distribution of epi-thermal neutron fluxes without obeying the rule of 1/E; α is spectrum coefficient expressing spectrum deviation from the rule of 1/E and it has a value in range [-1, 1]; σ(E) [cm^2] is neutron capture cross-section for reaction (n, γ) at energy E in unit of barn (1 bar = 10^{-24} cm^2); N_A is Avogadro number (≈ $6{,}023\times10^{23}$ mol^{-1}); θ(%) is abundance or isotope rich; γ(%) is gamma-emitting probability of interest; ε_p(%) is counting efficiency at energy peak of interest; M($g.mol^{-1}$) is atomic mass of element; $Q_0 = \frac{I_0(\alpha)}{\sigma_0}$; and $R_{Cd} = \frac{A_{sp}(bare)}{A_{sp}(Cd)}$ is cadmium ratio.

In order to measure neutron flux, it is used the standard foils of gold for activation through reaction of $^{197}Au(n,\gamma)^{198}Au$. Gold has characteristics as follows: E_γ = 411 keV; γ = 95%; $T_{1/2}$ = 2.695 days, $I_0 = 1550 \pm 28$ bars; $\sigma_0 = 98.65 \pm 0.09$ bars; and $Q_0 = I_0/\sigma_0 = 15.71 \pm 0.28$ [1, 2].

III. EXPERIMENTAL

1. Equipment and tools

* Multi-function water-filled Howitzer using an isotope neutron source has characteristics as follows (see Figure 1): It is a cylindrical aluminum tank with hight of 1.2 m and diameter of 1.2 m. The top of the tank is a cover of transparent plastic, and around the tank is two cylindrical aluminum shells. There is an insulating resin layer between the two shells. There is distilled water in the tank. Tank base is iron holder. There are ionic exchanger, water-circulatory pump and water heater for changing temperature of water beside the tank [1].

Figure 1. Multi-function water-filled Howitzer using an isotope neutron source was made in the Nuclear Research Institute.

* Neutron source of ^{252}Cf (began in Russia) with activity of 429 MBq (11.6 mCi) on 19th May 2011 and intensity of $5x10^7 \pm 8\%$ (n/s); source shell made in steel; cylindrical source core with diameter of 3.4 mm and lengh of 3 mm; external sizes (including the shell) with diameter of 7 ± 0.29 mm and lengh of 15 ± 0.35 mm [3].

* Neutron source of ^{241}Am-Be (began in South America) with activity of 37 GBq (1 Ci) on 31st May 1999 and intensity of 10^7 n/s [4].
* Standard activation foils of ^{197}Au with purity of 99.99%, diameter of 1.27 cm and thickness of 0.05 mm) with various masses (114.5 – 209.5 mg). Cadmium boxes with thickness of 0.5 mm and internal diameter of 2.54 mm.
* Gamma spectrometer: Using HPGe plane detector of ORTEC company with relative counting efficiency of 58% (Crystal sizes of 69.4 x 67.1 mm^2). The spectrometer is coupled with the spectrum receiving and processing code of Gammavison-32. Counting efficiency at the center and close to surface of the detector is 10.52% at gamma peak of 411 keV for ^{198}Au [5].

2. Activation and measurement of specific activity for bare foils

Experimental arangement for activating bare gold foils is shown in Figure 2. 13 gold foils are put up right-side aluminum bar with distances from the source to be 0, 1, 6, 11, 16, 21, 26, 31, 36, 41, 46, 51 and 56 cm, respectively. One gold foil is put up left-side aluminum bar with distance of 26 cm from the source (This foil is used to check an influence on neutron shielding of the foils). Typical gamma spectrums of the bare foils for ^{252}Cf and ^{241}Am-Be sources are shown in Figures 3 and 4, respectively. The measured results and calculation ones of specific activities for two bare foils (the same positions with distance of 26 cm from the source but in two directions) gave values of very small errors. It is proved that influence on neutron shielding when simultaneous irradiation of many foils in the Howitzer is negligible, and it does not significantly affected measured results. Experimental arangement for ^{241}Am-Be source is similar also.

3. Activation and measurement of specific activity for foils with cadmium cover

Experimental arangement for activating gold foils with cadmium covers for ^{252}Cf and ^{241}Am-Be sources is also similar to bare foils.

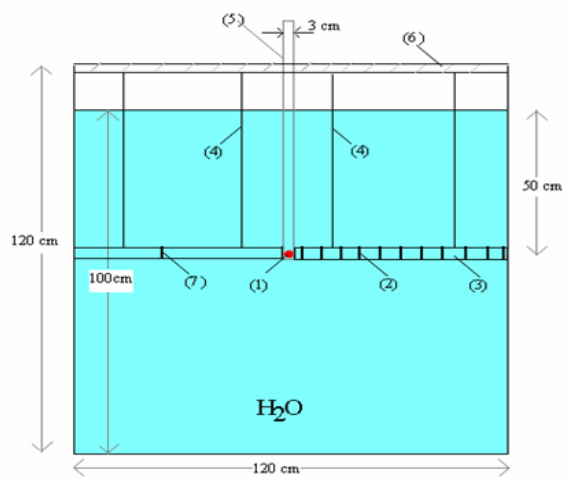

Figure 2. Experimental arangement for activating bare gold foils with symbols as follows: (1) ^{252}Cf source, (2) ^{197}Au foil, (3) aluminum bar, (4) hanging wire, (5) pipe to keep neutron source, (6) Howitzer cover, (7) Position of gold foil is used to check an influence on neutron shielding of the foils.

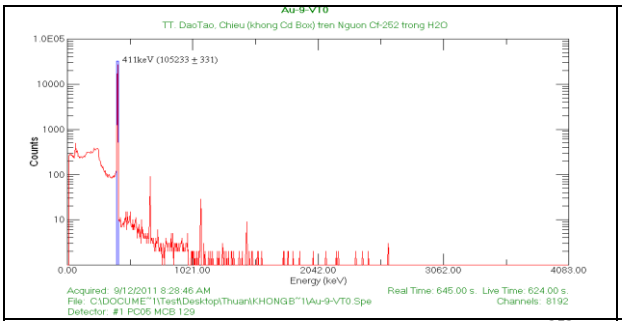

Figure 3. Gamma spectrum of bare gold foil for ^{252}Cf source.

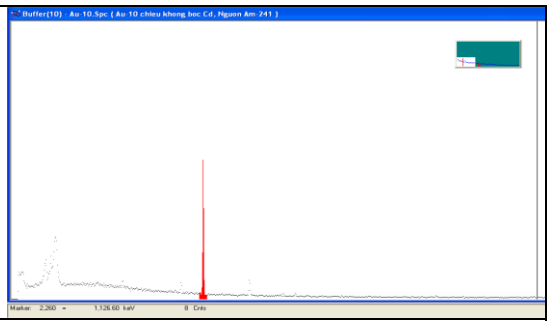

Figure 4. Gamma spectrum of bare gold foil for ^{241}Am-Be source.

IV. RESULTS AND DISCUSSION

Measured and calculated results of thermal (Φ_{th}), epi-thermal (Φ_{epi}) and total fluxes (Φ_{tot}) at 13 positions for ^{252}Cf source and 7 ones for ^{241}Am-Be source in direction of horisontal radius are shown in Tables 1 and 2, respectively (relative errors of flux determination are from 10% to 18%). Their illustration graphs are shown in Figures 5 and 6, respectively.

Table 1. Flux values of ^{252}Cf source.

Position (cm)	Φ_{th} (n.cm^{-2}.s^{-1})	Φ_{epi} (n.cm^{-2}.s^{-1})	Φ_{tot} (n.cm^{-2}.s^{-1})
0	252685	2344.33	255029
1	263088	2628.87	265717
6	145813	970.04	146783
11	48352	224.80	48576
16	14634	56.39	14690
21	3856.9	16.60	3873.5
26	1231.9	5.30	1237.2
31	451.44	1.92	453.36
36	157.76	0.65	158.41
41	60.42	0.21	60.63
46	26.33	0.10	26.43
51	11.36	0.00	11.36
56	4.00	0.00	4.00

Table 2. Flux values of ^{241}Am-Be source.

Position (cm)	Φ_{th} (n.cm^{-2}.s^{-1})	Φ_{epi} (n.cm^{-2}.s^{-1})	Φ_{tot} (n.cm^{-2}.s^{-1})
1	8903.30	106.88	9010.18
6	5480.95	42.24	5523.19
11	2217.54	11.66	2229.20
16	823.45	3.04	826.49
21	493.09	1.18	494.27
26	212.21	0.42	212.63
31	28.41	0.29	28.70

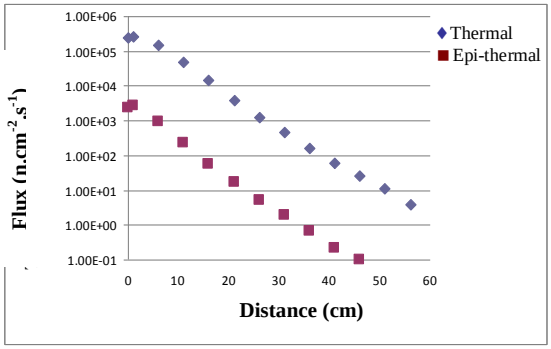

Figure 5. Distribution of thermal and epi-thermal neutron fluxes for ^{252}Cf source.

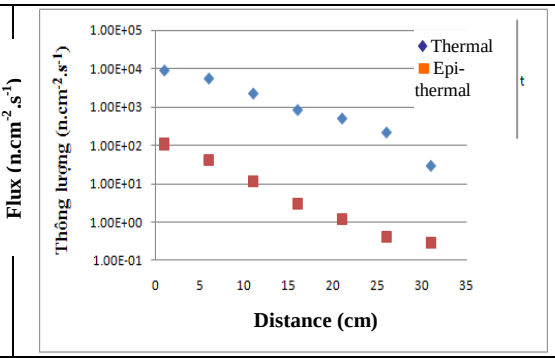

Figure 6. Distribution of thermal and epi-thermal neutron fluxes for ^{241}Am-Be source.

The results in Tables 1 and 2, Figures 5 and 6 are shown that maximum value of neutron flux is at 1 cm distance from the source and it is rapidly decreased with distances. Values of neutron flux are very small at close to the aluminum cover of Howitzer, and values of epi-thermal neutron fux are equal to zero from distance of 56 cm onwards.

V. CONCLUSION

The report was implemented for experimental determination of flux distributions of thermal and epi-thermal neutrons in the water-filled Howitzer in direction of horisontal radius by activation of 27 gold foils for

^{252}Cf source and 14 ones for ^{241}Am-Be source including bare foils and foils with cadmium covers, measuring gamma spectrums and calculating fluxes by the method of cadmium ratio.

The results of thermal and epi-thermal flux distributions for ^{252}Cf and ^{241}Am-Be sources in direction of horisontal radius could be suported for problems on activation analysis in the future. When know source intensity, thermal and epi-thermal neutron fluxes at the positions for determining content of an element of interest by neutron activation analysis, it could be found an optimal position for sample activation so that analytical results are the most precision.

VI. ACKNOWLEDGEMENTS

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REFERENCES

[1] Nguyen Van Hung at el. *Studying, designing and making a system of experimental equipment in order to measure some physical characteristics of neutron, neutron activation analysis and dosimetry for serving training activities on nuclear manpower*. Report on research project at Ministry level for 2010-2012 (in Vietnamese), 03/10/NLNT Code, Ministry of Science and Technology, 2012.

[2] Ho Manh Dung. *Handbook on neutron activation analysis.* Nuclear Research Institute (in Vietnames), Dalat, 2007.

[3] R.C. Martin et al. *Production, distribution, and application of Californium-252 neutron sources.* Oak Ridge National Laboratory, USA, 1999.

[4] A.M. Hassan et al. Neutron activation analysis of saudi hermatite and phosphate sample using the ^{241}Am-Be neutron irradiation facility. *JKAU: Sci*., Vol.6, pp.105-122 (1414 A.H./1994 A.D.), 1994.

[5] K. Debertin et al. *Gamma- and X-ray spectrometry with semiconductor detectors*. USA, 1988.