Uncertainty analysis of power variation for one typical research reactor

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Abstract

Power is one of the main characteristics of each research reactor which determines amount and diversity of its applications. Stability of power during irradiation especially for long time is one of the key parameters preventing from uncertainty in anticipated activity. The uncertainty analysis of the power variations for one month operation of the Tehran Research Reactor (TRR) with 5 MW power is conducted precisely. Variations of the TRR power is determined by measurement of net peak areas of 1332 keV gamma rays of ^{60}Co neutron activated monitors. The in-core irradiation position and beam tube results indicate about 1% and 3% power variation respectively. The accuracy in the other parameters such as irradiation time, samples weight, irradiation position and counting system have also some effects on the uncertainty of the power variation. With considering the effects of the mentioned parameters, the stability of reactor power during experiment is concluded.

Keywords: R**esearch reactor, uncertainty analysis, power variations, irradiation, activity.**

Introduction

The uncertainties in a typical research reactor such as Tehran Research Reactor (TRR) is highly dependent to a numerous parameters. Two research work are recently done about uncertainty of neutron flux and effective parameters in samples irradiation at 5 MW power research reactor of McMacter [1, 2]. One of the uncertainty sources of activity in long time irradiation from some days to month is power variations which could cause changes in neutron flux. The power variations during one month of the TRR are accurately analyzed and its effects are determined. It is worth mentioning that with considering the continuous calibration of equipment, the results of this study could be established for other core configurations of reactor.

Preparation of the materials

The flux mapping technique using neutron activation analysis is one of the neutron flux measurement methods. The neutron flux distribution in every height of irradiation positions in the core are unique and the maximum flux happens in the range of 20 to 40 cm of active fuel height of the TRR fuel [3]. Some pure samples such as Cobalt, Gold, Copper or Indium are used as flux monitor for neutron activation analysis and neutron flux measurement. Samples are irradiated in the in-core irradiation position for neutron flux monitoing and meaturment. The neutron flux could be measured accurately using irradiation of bare and covered gold with Cd-foil. Flux mapping and absolute flux measurement are obtained by irradiation of Cobalt monitor in irradiation position. The uncertainty would be minimized if a pure sample are irradiated in low powers, the irradiation position is carefully determined, irradiation time and weight of sample being accurate, and correction of cooling time and counting are applied. Also, it is necessary to calibrate energy and efficiency to obtain high quality of results in gamma spectrometry. After calculation and taking all the mentioned above considerations into account, thermal neutron flux could be determined from calculation or experimental measurement of reaction rate [4].

The net peak area of ^{60}Co of gamma spectrum has direct relation with neutron flux and therefore reactor power. Then, variation of this area indicates the variation of neutron flux in reactor. The irradiation is conducted in one month due to isotopic abundance and large absorption cross section of ^{59}Co. The investigation is performed for two positions of beam tube B and F6 in-core position. Unlike locating samples in the F6 position, the insertion and removing of samples in the beam tube is done pneumatically. In each experiment, two samples are send as possible as concurrently and consequently for minimizing uncertainty of irradiation time. After irradiation and adequate cooling time, the samples are counted with High Pure Germanium (HPGe) detector for 2000 s and the spectrum of the samples are recorded by Gamma Vision Software.

Results and discussion

The net peak areas of 1332 keV gamma ray for irradiated cobalt monitor in the beam tube and the in-core position at one operation cycle is given in Figure 1 and Figure 2. The variations of net area indicate the variation of neutron flux and reactor power in appropriate locations during irradiation period. For having a relation between net peak areas and absolute neutron flux, measurement of absolute neutron flux in irradiation position is done through irradiation of a bare and Cd-covered gold foil in the last day of irradiation program.

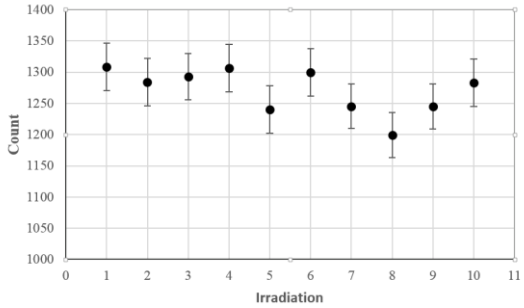

Figure 1. Net peak area for irradiation in beam tube B

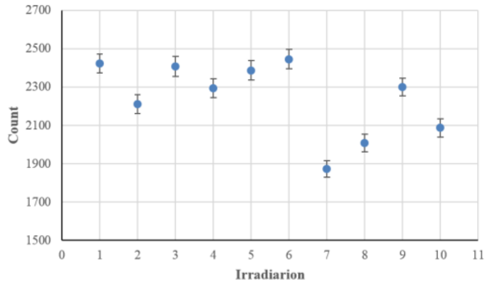

Figure 2. Net peak area for in-core irradiation

The variation of neutron flux which are resulted from above figures are given in Figure 3 and Figure 4.

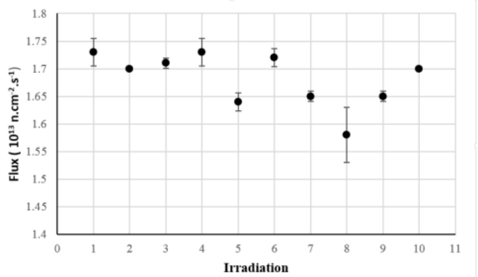

Figure 3. Thermal neutron flux for the beam tube B

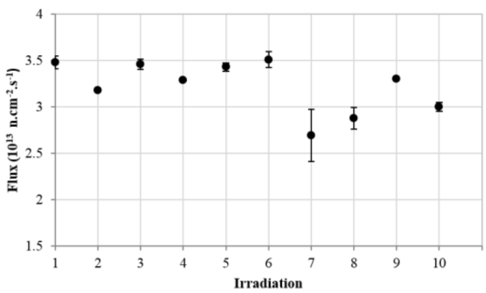

Figure 4. Thermal neutron flux for core

The statistical analysis of results is given in Table 1 and Table 2. It is worth mentioning that two samples are irradiated in each irradiation process and the average of these two values are used for final result in each day. As could be seen from Table 2, the variation of flux in beam tube is less than the in-core irradiation position due to automated insertion and removal of samples.

Table 1- The statistical analysis of Net peak area

Quantity	Core	Beam tube
$\bar{N}$	2243	1270
N_{max}	2446	1308
N_{min}	1873	1199
SD[1]	196	36
Final count	2243±62	1270±11
Uncertainty	62 (2.7%)	11 (1%)

The thermal neutron flux of in-core and beam tube are calculated using counts of gold foil irradiated samples and given in Table 2.

Table 2. Statistical analysis of thermal neutron flux

Quantity	Core	Beam tube
ϕ_{avg}	3.22×10^{13}	1.68×10^{13}
ϕ_{max}	3.51×10^{13}	1.73×10^{13}
ϕ_{min}	2.69×10^{13}	1.58×10^{13}
SD	0.28×10^{13}	0.049×10^{13}
Final count	$(3.22\pm0.08)\times10^{13}$	$(1.68\pm0.015)\times10^{13}$
Uncertainty	0.08×10^{13} (2.7%)	0.015×10^{13} (1%)

Conclusions

The variation of neutron flux and activity of samples for a specific power in one month operation at the TRR is strictly investigated. It is indicated that the biggest amount of uncertainty due to power variation in beam tube is less than 1%. The uncertainty for the in-core irradiation position is some more and is about 3%. The uncertainty of in-core position is bigger due to associate uncertainties from irradiation time, cooling time and also irradiation position of the samples. This is concluded that there is a very low uncertainty in activity of samples due to variation of power during irradiation program.

References

[1] Standard deviation

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