Inventory Analysis of Radiological for Graphite Thermal Column from Triga Mark II Reactor, Bandung

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Abstract :

The inventory analysis of radiological for graphite thermal column from Triga Mark II reactor, Bandung has been presented. The age of Triga Mark II reactor is more than 45 years, therefore the reactor certainly will be decommissioned sooner or later. Before being decommissioned, one important thing that should be done is the inventory analysis of radiological of its all component. The data of the inventory analysis is needed to calculate the radioactive waste, which needed budget for decommissioning. The graphite thermal column is the most significant solid radioactive waste. The inventory analysis of the radiological for graphite thermal column could be calculated by computer code ORIGIN2. This study can be concluded that the inventory analysis of radiological for graphite thermal column from Triga Mark II reactor, Bandung, after being shut down for 5 years is H-3, C-14, Fe-55, Mn-54, Co-60, Eu-152 and Eu-154 for graphite; Al-28, Fe-55, Co-60, Ni-63 and Zn-65 for aluminum cover; and Cl-36, K-40 and Fe-55 for boral cover, with total specific activity for inside increment is $1.87x10^3$ Bq/g for graphite and $1.15x10^4$ Bq/g for aluminum; and for outside increment is 2.43x10 Bq/g for graphite; $1.52x10^2$ Bq/g for aluminum and 8.8x10 Bq/g for boral cover. If it is being stored for 30 years, the dominant radionuclide is H-3, Co-60 and Eu-152.

Keywords: graphite thermal column, inventory analysis, mulyono daryoko

1. Introduction

The age of Triga Mark II, reactor, Bandung is more than 45 years **[1]**, therefore the reactor certainly will be decommissioned sooner or later. Before being decommissioned, one important thing that should be done is the inventory analysis of radiological of its all component. The data of the inventory analysis is needed to calculate the radioactive waste, which needed budget for decommissioning. The graphite thermal column is the most significant solid radioactive waste, and must be calculated.

Following shutdown and discharge of irradiated fuel, the residual radionuclide inventory of nuclear reactor falls into two categories **[2,3]**:

1. Neutron activated materials, which are located in and near the core and have been irradiated by neutrons. The reactor core is the most activated part of the reactor structure. The portion of the reactor exposed to relatively low neutron fluxes is essentially the biological shield, usually made of concrete and steel reinforcements. The graphite thermal column is a one of the important component are located near the core. The processes giving rise to the radionuclide inventory are described in the nuclear reaction of Table 1 **[2,3]**
2. Contaminated materials, which arises from the activation of the corrosion and erosion products conveyed by the coolant and from the dispersion of the irradiated fuel and fission products through cladding breaches. In addition, contamination results from leakages in the primary circuit, processing and storage of radioactive effluents and wastes, maintenance and repair activities, fuel discharging operations and working accidents. Airborne contamination may also give rises to a deposit of radioactive substances on walls, ceilings and in the ventilation system.

The graphite thermal column was made from graphite material and covering with aluminum alloy (Al 60-61-T651) in the inside, and the outside covering with aluminum alloy and boral. The graphite thermal column providing a source of well thermalized neutron suitable. The graphite thermal column position was showed in Figure 1.

The radioactivity of graphite only arising 1 sours, is activation radionuclide from graphite, aluminum cover and boral cover. Important radionuclide from graphite are: H-3, C-14, Fe-55, Co-60, Nb-94, Eu-152 and Eu-154; aluminum are: Fe-55, Ni-63 and Zn-65; boral are: Cl-36, K-40 and Fe-55.

This research have been carry out to analysis of radiological graphite thermal column component, using simulation of computer code ORIGEN2.

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The parameter as follows must be available**[4,5]**:

1. The composition and weight of component of graphite thermal column
2. The reactor power
3. The effective full power years (efpy)
4. Times year after shut down.

Table 1. The most important activation reactions considered

Parent	Nuclear reaction	Daughter nuclide	Principal emissions	Half-life of daughter (a)	Abundance of parent nuclide in parent element (%)
Li-6	n,α	H-3	β^-	12.3	7.5
C-13	n, γ	C-14	β^-	5730	1.1
N-14	n, p	C-14	β^-	5730	99.6
Na-23	n,2n	Na-22	β^+, EC	2.6	100
Na-23	γ,n	Na-22	β^+, EC	2.6	100
Cl-35	n, γ	Cl-36	β^- (β^+, EC)	301000	75.8
K-39	n, p	Ar-39	β^-	269	93.3
Ca-40	n, γ	Ca-41	EC	103000	96.9
Fe-54	n, p	Mn-54	EC, γ	0.86	5.9
Mn-55	n,2n	Mn-54	EC, γ	0.86	100
Fe-54	n, γ	Fe-55	EC, X	2.7	5.9
Ni-58	n, γ	Ni-59	EC, X	76000	68.3
Ni-62	n, γ	Ni-63	β^-	100	3.6
Co-59	n, γ	Co-60	β^-, γ	5.3	100
Zn-64	n, γ	Zn-65	EC, β^+	0.67	48.6
Zr-92	n, γ	Zr-93	β^-	1500000	17.1
Mo-92	n, γ	Mo-93	EC, X	3500	14.8
Nb-93	n, γ	Nb-93m	IT, X	15.8	100
Nb-93	n, γ	Nb-94	β^-, γ	20000	100
Mo-94	n, p	Nb-94	β^-, γ	20000	9.3
Mo-98	n, γ	Tc-99	β^-	213000	24.1
Ag-107	n, γ	Ag-108m	EC, γ	130	51.8
Ag-109	n, γ	Ag-110m	β^-, γ	0.68	48.2
Sn-124	n, γ	Sb-125	β^-, γ	2.76	5.8
Ba-132	n, γ	Ba-133	EC, X, γ	10.5	0.1
Eu-151	n, γ	Eu-152	EC, X, β^-, γ	13.5	47.8
Eu-153	n, γ	Eu-154	β^-, γ, X	8.6	52.2
Eu-154	n, γ	Eu-155	β^-, γ, X	4.76	0
Ho-165	n, γ	Ho-166m	β^-, γ, X	1200	100

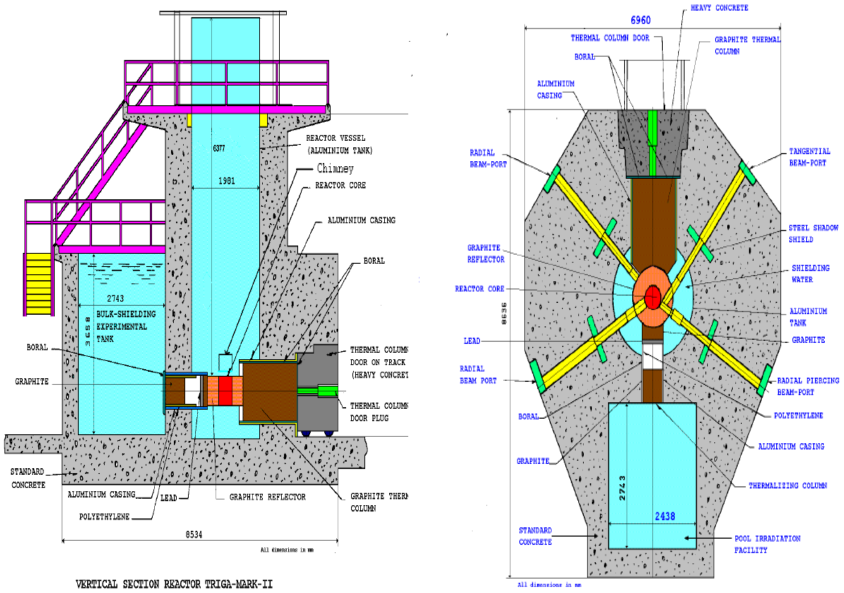

Figure 1. The vertical and horizontal section of reactor Triga Mark II, Bandung

2. Material and Methods

The concentration of radionuclide as the time function in the core of nuclear reactor could be write by differential equitation non homogeneous order 1 as follows:

[illegible] [1]

where :

χi = atomic density of nuclide i
N = total of nuclide
lij = disintegration fraction of radioactive from j to i
λi = constant of disintegration radioactive of nuclide i
ϕ = flux neutron average
fik = fraction of neutron adsorbed of nuclide k to nuclide i
σk = spectrum of neutron adsorbed average of nuclide k
ri = rate of removal of nuclide i from system
Fi = feed rate of nuclide i

In the homogeneous system:

$$\dot{X} = AX \qquad [2]$$

where

$\dot{X}$ = derivation to time of nuclide concentration (column vector)
A = matrix of nuclide transition
X = concentration of nuclide (column vector)

This equation have solutions as follows:

[illegible] [3]

where:

X(t) = the concentration of nuclide at t
X(0) = the concentration vector of initial nuclide
T = the time of stage calculation final

By this methods, the concentration of all nuclide at stage of calculation final could be calculated and saved, and than there are could be stepped forward as output, and using as initial concentration condition for stage as follows.

In this research the ORIGEN2 using to calculation of weigh fraction (gram), radioactivity (Ci) and thermal power(watt). Block diagram of using the ORIGEN2 for analysis of graphite thermal column shows at Figure 2.

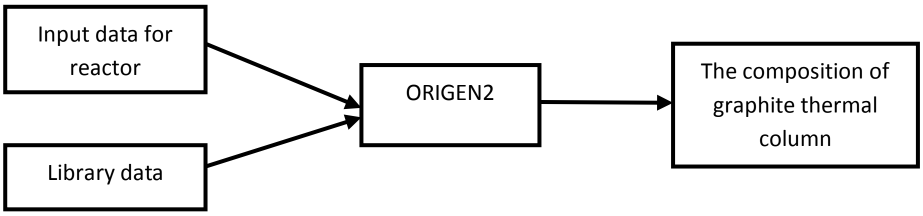

Figure 2. Blok diagram for using ORIGEN2 for analysis

3. Result and Discussion.

The composition data of graphite thermal column component showed for example on Table 2. The Effective Full Power Year (EFPY) of reactor Triga Mark II Bandung to carry out for literaturs, and then to discussion with manager and operators of Triga Mark II reactor, Bandung and to carry out of log book operation, than discribe datas as follows:

1. For years operation 1965 - 1971 with in power 250 kW, EFPY = 2 years
2. For years operation 1971 - 1996 with in power 1 MW, EFPY = 6,68 years
3. For years operation 2001 – now with in power 2 MW, EFPY = 0,68 years

The methods of flux carried out for the graphite thermal column component could be conducted, both for calculation by distank quadrate and for literatures.

The estimation of neutron flux in the round of reactor core could be approach of sperical symmetry and approach of point sours and radiation doses compare the reverse side to distank quadrate, and showed in Figure 3.

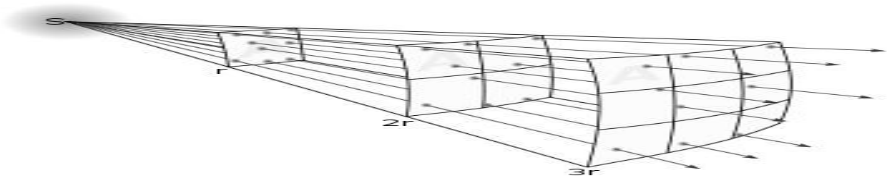

Figure 3. The radiation exposure to inside of spherical symmetry room.

By graphic shows that the lighting intensity for two time distance from sours, product exposure attenuation one-fourth times, because the disperse intensity from fourth times of the width. The Figure 3 show, if the radiation sours S rays radiation by spherical symmetry produce radiation dose D for distance r, 2r and 3r, reverse to quadratic distance as follows:

$$D_r:D_{2r}:D_{3r} = 1/r^2:1/(2r)^2:1/(3r)^2 \qquad [4]$$

The flux data also could be from literatures, with in approach that the value of flux component from the Triga Mark II reactor one and other straight proportioned with the reactor power. Then, the flux of graphite thermal column reactor Triga Mark II is identical with reactor Kartini, Yogyakarta. The Table 5 shows the flux of the component of reactor Kartini. From this Table, the flux of the graphite thermal column of reactor Triga Mark II, Bandung (inner part) is 4.32E+10n/cm^2.second for 250 kW; 1.73E+11 n/cm^2 second for 1000kW; and

3.46E+11n/cm^2. second for 2000kW; and for outer part 3.22E+10n/cm^2. second for 250 kW; 1.29E+11n/cm^2. second for 1000 kW; and 1.58E11n/cm^2. second for 2000 kW.

The data compositions, EFPY and flux above are the main data for calculation to the inventory analysis of radiological for graphite thermal column from Triga Mark II reactor, Bandung, after being shut down for 5 years, by computer code origen2.

Table 2. The graphite composition

Material of construction	Elements present	Concentration (ppm)
Graphite	*Lithium*	0,1
	Carbon	10^6
	Nitrogen	4
	Chlorine	4,3
	Calcium	41
	Iron	4,3
	Cobalt	0,012
	Nickel	3,65
	Niobium	1
	Silver	0,01
	Tin	0,05
	Barium	1
	Samarium	0,02
	Europium	6×10^{-4}
	Mercury	0,04
	Uranium	0,1

The results was shown in Figure 4, Figure 5, Figure 6 and Figure 7. From this figures shown that the inventory analysis of radiological for graphite thermal column from Triga Mark II reactor, Bandung, after being shut down for 5 years is H-3, C-14, Fe-55, Mn-54, Co-60, Eu-152 and Eu-154 for graphite; Al-28, Fe-55, Co-60, Ni-63 and Zn-65 for aluminum cover; and Cl-36, K-40 and Fe-55 for boral cover, with total specific activity for inside increment is 1.87x10^3 Bq/g for graphite and 1.15x10^4 Bq/g for aluminum; and for outside increment is 2.43x10 Bq/g for graphite; 1.52x10^2 Bq/g for aluminum and 8.8x10 Bq/g for boral cover. If it is being stored for 30 years, the dominant radionuclide is H-3, Co-60 and Eu-152. The data of the inventory analysis is one part for needed to calculate the radioactive waste, which needed budget for decommissioning, because the graphite thermal column is the most significant solid radioactive waste.

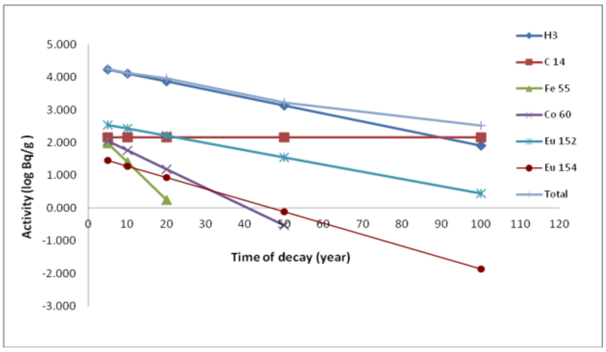

Figure 4. Inventory of graphite thermal column (inner part, 250 kW, 1MW and 2MW)

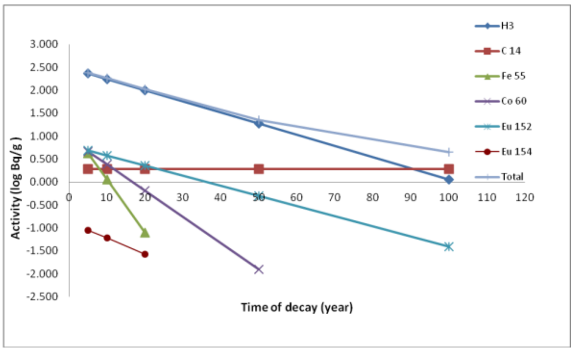

Figure 5. Inventory of graphite thermal column (outer part, 250 kW, 1MW and 2MW)

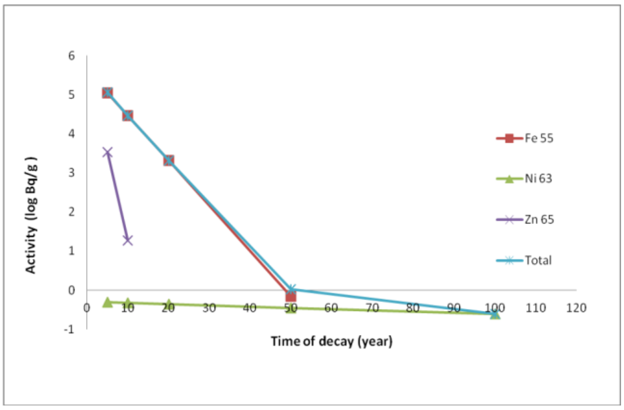

Figure 6. Inventory of graphite thermal column, cover aluminum(inner part, 0.250, 1 and 2MW)

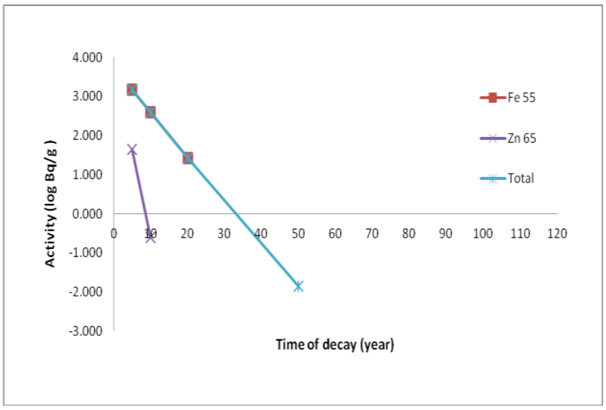

Figure 7. Inventory of graphite thermal column, cover aluminum (outer part, 0.250, 1 and 2MW)

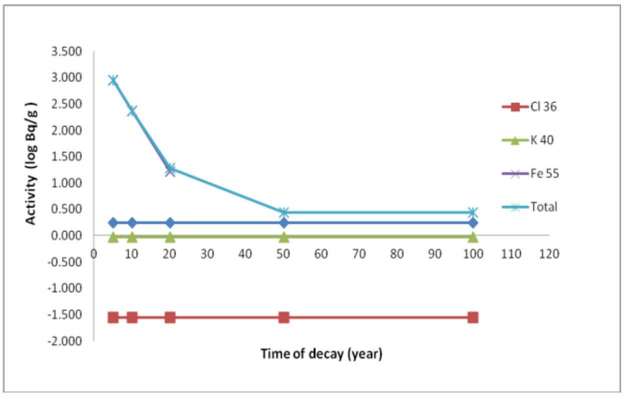

Figure 8. Inventory of graphite thermal column, cover boral (outer part, 250 kW, 1MW and 2MW)

4. Conclusion

The inventory analysis of radiological for graphite thermal column from Triga Mark II reactor, Bandung, after being shut down for 5 years is H-3, C-14, Fe-55, Mn-54, Co-60, Eu-152 and Eu-154 for graphite; Al-28, Fe-55, Co-60, Ni-63 and Zn-65 for aluminum cover; and Cl-36, K-40 and Fe-55 for boral cover, with total specific activity for inside increment is 1.87×10^3 Bq/g for graphite and 1.15×10^4 Bq/g for aluminum; and for outside increment is 2.43x10 Bq/g for graphite; 1.52×10^2 Bq/g for aluminum and 8.8x10 Bq/g for boral cover. If it is being stored for 30 years, the dominant radionuclide is H-3, Co-60 and Eu-152.

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