Criticality study of bandung TRIGA 2000 reactor plate type fueled

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Abstract. The purpose of this research is to study of replacing the type of cylinder fuel in the TRIGA 2000 reactor into another type of plate. We modeled the core of the TRIGA 2000 reactor geometry equipped with a moderator, a graphite reflector, AgInCd as control rods, and a reactor tank without changing the dimension of the reactor core. The composition of the fuel was U₃Si₂Al with a 19.75% enrichment and 2.96 gU/cm³ density. Criticality study was carried out on a 5x5 core configuration, consisting of 16 fuel assemblies and 4 control fuel assemblies. Simulation has been done using the MCNPX. It has been found that the $k_{eff}$ value when all of the neutron absorbers withdrawn was $1.07100 \pm 0.00017$.

1. Introduction
The original TRIGA patent," Reactor with Prompt Negative Temperature Coefficient and Fuel Element Therefor," was filed on May 9, 1958 and assigned to General Atomic on March 31, 1964. The fuel is UZrH with stainless steel cladding [1]. The fuel element is depicted in Figure 1. The TRIGA reactors has been operated by some developing countries for support nuclear science and technology research. Indonesia has two TRIGA reactors operated by BATAN. One of which is TRIGA 2000 reactor located in Bandung. The TRIGA 2000 reactor mainly is used for training, research and isotope production. The permitted operating maximum power is 2 MW. Initially the TRIGA 2000 reactor was operated at 250 kW in 1964. In 1971, BATAN was able to increase its power to 1 MW and currently the reactor is capable of operating at power 2 MW [2].

At the TRIGA user meeting dated on March 24, 2010 in Marrakesh, the General Atomic announce to stop the manufacture of the cylindrical type fuel elements [3]. Consequently, the operation of all TRIGA reactors will be disrupted when the fuel currently used is exhausted. It is necessary to work out a solution to enable the TRIGA reactor to operate continually. One of the possibility is replacing the cylinder type fuel into plate type fuel.

In this study, we purposed to change the cylinder type fuel of the TRIGA 2000 reactor with plate type fuel as same as the type used by the RSG-GAS, by means of calculating criticality value. Similar research was done by Tjiptono but on Kartini reactor [4]. This solution was taken with the aim of reducing the dependence of buying imported fuel elements, because BATAN in this case PT. INUKI has been able to make the plate type fuel elements. In this study, we reported the obtained parameter...
criticality of neutronic aspect using software MCNPX (Monte Carlo N Particle eXtended) developed by Los Alamos National Laboratory [5].

Figure 1. Standard TRIGA fuel element [1].

2. Numerical Methods
The fuel plate used in this study was $\text{U}_3\text{Si}_2\text{Al}$ with a density of 2.96 g/cm$^3$ and 19.75% enrichment, the cladding is coated by aluminum alloy material. Low enrichment fuel has been used in many countries that convert high enrichment fuels to low enrichment [6,7,8]. Each fuel element has 21 fuel plates and the control element has 15 fuel plates. There are 4 control AgInCd rods with stainless steel as the cladding. The parameters and the shape of the fuel and the control element are written in the Table 1 and Figure 2, respectively.

| Parameter                                             | Value                        |
|-------------------------------------------------------|------------------------------|
| Fuel element dimension and control element            | 77.1 x 81 x 600 mm           |
| Thickness of the fuel plate                           | 1.3 mm                       |
| Width of the cooling channel                          | 2.55 mm                      |
| Total of $\text{U}_3\text{Si}_2\text{Al}$ plate per fuel assemblies | 21                           |
| Total of $\text{U}_3\text{Si}_2\text{Al}$ plate per control assemblies | 15                           |
| Thickness of the fuel cladding                        | 0.38 mm                      |
| Fuel material                                         | $\text{U}_3\text{Si}_2\text{Al}$ |
| Density                                               | 2.96 g/cm$^3$                |
| Neutron absorber                                      | AgInCd                       |
| Material absorbent cladding                           | SS-321                       |
| Thickness absorbent cladding                          | 0.85 mm                      |
The geometry of the TRIGA 2000 reactor simulated was the moderator, graphite reflector, and reactor tank. The TRIGA 2000 reactor is a pool reactor, shown in Figure 3 below.

![Figure 3. The side view of TRIGA 2000 reactor](image)

Geometry reactor TRIGA 2000 Bandung has a diameter of 53 cm [10], while the size of the fuel plate device is $7.71 \times 8.1$ cm so that the maximum amount of fuel plates that can be used in reactor TRIGA 2000 Bandung is 20 pieces with $5 \times 5$ position where the center the core can be used for 1 CIP (*central irradiation position*) and 4 IP (*irradiation position*), shown in Figure 4.

![Figure 2. (a) Fuel element design (b) control element design [9].](image)
Figure 4. New core configuration

Criticality calculation has been done using MCNPX software with all control rods in fully up position and the space was filled with 20 fuel assemblies. The number of ksrc is one per plate and the repetition is 100,000 times. The final $k_{eff}$ value was obtained after 250 cycles by ignoring the first 50 cycles.

3. Results and Discussions

![Figure 5](Image)

(a) (b)

Figure 5. TRIGA geometry simulated by MCNPX viewed from (a) XZ and (b) XY plane.

The TRIGA geometry from the side and top view are shown in Figure 5 (a) and (b). It has been obtained that the final $k_{eff}$ value is $1.07100 \pm 0.00017$. This result is consistent with that of the research conducted by Tjiptono [4]. Geometry modeled only the reactor core without beamport, thermalizing column and thermal column. Researchers will make improvements to the core and the value of ksrc can be multiplied so that the criticality value is better. Based on criticality calculation, replacement of the TRIGA 2000 fuel into the type of plate is very possible.

4. References

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