

The study and analyze the operation of the Bandung TRIGA research reactor using plate-type fuel elements.

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Abstract. In preparation the conversion of Bandung TRIGA reactor into a plate-type reactor fuel, will be designed new reactor core using MCNP program. In this study will be analyzed several alternatives core configurations, which are formed of various the control elements position and using existing graphite reflector. The study and analysis includes the excess reactivity, shutdown margin, flux distribution, power distribution and core management. By comparing the magnitudes for all the core configurations will be obtained TRIGA reactor core converted optimal, safe and controlled. The configuration chosen as the best core configuration reactor core consists of square-lattice size of 5 x 5, with a maximum charge of 21 position fuel elements including control four elements. The control rods positioned on the grid B-2, D-2, B-4, and D-4. The position on the grid C-3 and on the grid A-1, A-5, E-1, and E-5 will be used for the irradiation facilities. Due to these irradiation facilities, the number of fuel elements including control elements can only as many as 20 positions. Thermal neutron flux $2.89 \times 10^{13} \text{ cm}^{-2}.\text{sec}^{-1}$ on the center irradiation position (C-3) and $1.55 \times 10^{13} \text{ cm}^{-2}.\text{sec}^{-1}$ on irradiation position (A-1, A-5, E-1, and E-5)

Keywords: Bandung TRIGA reactor, plate-type fuel element.

1. Introduction

Since the General Atomic no longer produce TRIGA fuel elements and FFCR as continuity of Bandung TRIGA reactor operation could no longer be maintained. On the other hand, the National Nuclear Energy Agency of Indonesia has been able to produce plate-type fuel element which is currently used in the Serpong reactor. It should also be remembered that the majority of Bandung TRIGA reactor system is still relatively new. Therefore, the conversion of fuel elements from the standard TRIGA fuel into a fuel element plate-type is an alternative that is cheaper and easier to Bandung TRIGA reactor. This activity is intended to operate Bandung TRIGA research reactor by utilizing the existing TRIGA fuel elements. Meanwhile, to anticipate the supply difficulty of TRIGA fuel element, now is being prepared a study for the conversion of Bandung TRIGA fuel elements into a standard plate-type fuel. To achieve this objective, a new core with LEU fuel elements was developed. The new design is based on low enriched (19.7%) uranium silicides. In the planning the Bandung TRIGA reactor will be operated at maximum power of 2000 kW. For the cooling system, because the flow of coolant in the reactor core will use the forced convection flow, needs analysis and new design of the primary coolant system. This design is based on the data flow rate is required, so that the design of the reactor primary coolant system produced in accordance with the conditions of the planned reactor core. A delay tank will be designed to inhibit trips N-16 that will disintegrate before the cooling water back into the reactor tank and N-16 has decayed. Implementation of the program began in 2015 and preliminary design for neutronic and thermo-hydraulic be completed by the end of 2016. In this year a study is being done on neutronic.

2. A brief History of Bandung TRIGA Reactor

In early 2006, Bandung TRIGA reactors experiencing problems, such as: the emergence of bubbles of excessive, coming out of the reactor core reactor tank to the water surface. Therefore, the reactor is operated with a 1250 kW power. In addition burn-up FFCR there are up to 50% and the reactor building is old, needs to be strengthened in order to withstand earthquakes. So that the regulatory body decided to suspend the operating license Bandung TRIGA reactor for a while, until the problem is resolved. Accordingly, it is done in-depth study of Bandung TRIGA reactor, as consideration for deciding the continued operation of Bandung TRIGA reactor. Results of the study: Option-1, Bandung TRIGA reactor resumed operations with the purchase of fresh standard TRIGA fuel elements including purchasing new FFCR. It seems this option cannot be implemented. Option-2, Bandung TRIGA reactor to continue operating for 1000 kW by using standard TRIGA fuel elements are still exist and replace FFCR with control rod elements without fuel follower. Control rods without fuel followers have been made in BATAN Serpong and now are in the testing phase. Until currently Bandung TRIGA reactor still contained 125 fuel elements, seven of them are fresh fuel elements. Option-3, to convert Bandung TRIGA reactor standard fuel elements into fuel plate-type. Results of the study showed, by making possible changes to Bandung TRIGA core, can be converted TRIGA reactor core made of a square, which contains a maximum of 20 fuel elements, including four controls element, and five irradiation facilities position. The problems to be faced in the third option are to design, create and install the core, but the other benefits are fuel plate-type elements can be produced by BATAN. Option-2 and 3 are interconnected. When the above three options are not feasible, then the last option is implementation the decommissioning program.

3. Purpose of this study

Technical study is intended to provide assurance that it is technically Bandung TRIGA reactor can be converted into plat-type fuel element.

4. Scope of Study

This study will only discuss the feasibility and safety aspects of the operation Bandung TRIGA reactor converted, which uses plate-type fuel element, from the viewpoint of neutronic. This study will be conducted for one year, in 2015. If the aspect neutronic is feasible, then in the second year will be followed by a thermo-hydraulic study

5. Results of Study

Technical study of neutronic calculation of the Bandung TRIGA reactor using plate-type fuel elements, such as general criteria:

- The use of all available reactor systems today: reactors tank, thermal-thermalizing column, beam-ports, reflector, rotary specimen rack, primary and secondary cooling system.
- The use of technology that has been well known and tested: manufacture of plate-type fuel elements U_3Si_2-Al , and control elements: $Ag-In-Cd$

- Using full symmetry core configuration: symmetry power distribution and neutron flux, and ease to manage of fuel elements

Lattice core size is 5 x 5, because there are five irradiation positions facility, and then loaded with a maximum of 20 fuel elements, including control elements. Material control elements are Ag-In-Cd (85 : 10 : 5) w-% and fuel elements U_3Si_2 -Al, 178.6 g, with 19.75% enrichment and a density of 2.96 g.cc^{-1} . The control elements and the fuel elements are the same as that used in the Serpong reactor, Indonesia. The alternative control element position on the B-2, D-2, B-4, and D-4. The optimum TRIGA reactor core consists of 16 fuel elements, 4 control elements, one center irradiation position (CIP) on C-3, and four irradiation positions (IP) on A-1, A-5, E-1, and E-5. Thermal neutron flux $2.89 \times 10^{13} \text{ cm}^{-2}.\text{sec}^{-1}$ on the CIP and $1.55 \times 10^{13} \text{ cm}^{-2}.\text{sec}^{-1}$ on the IP. TRIGA reactor can be operated continuously for a minimum of 800 days in 1000 kW power, without the need to change the composition of fuel elements.

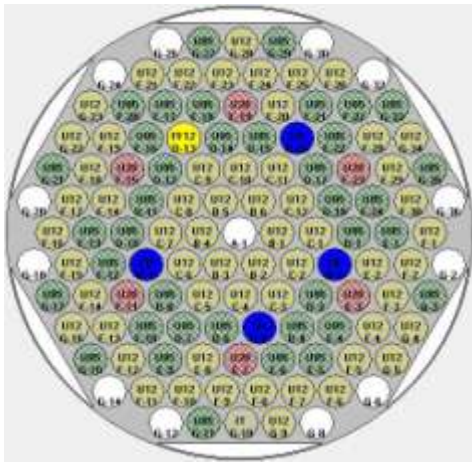


FIG. 1. TRIGA reactor core with standard fuel elements

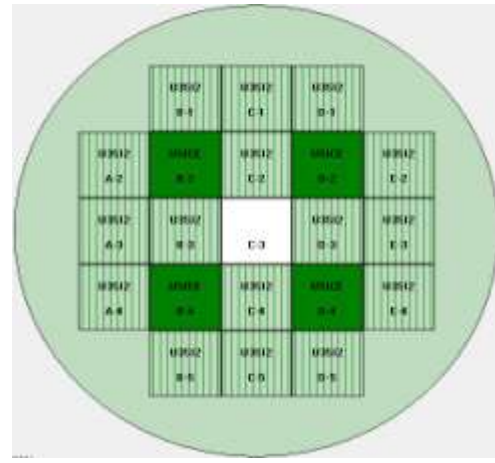


FIG. 2. TRIGA reactor core with plat-type fuel elements

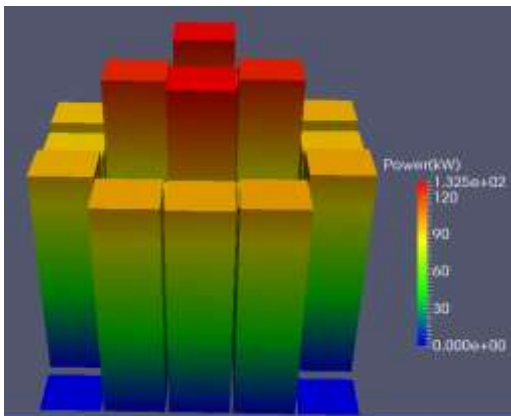


FIG. 3. Power distribution of each fuel element

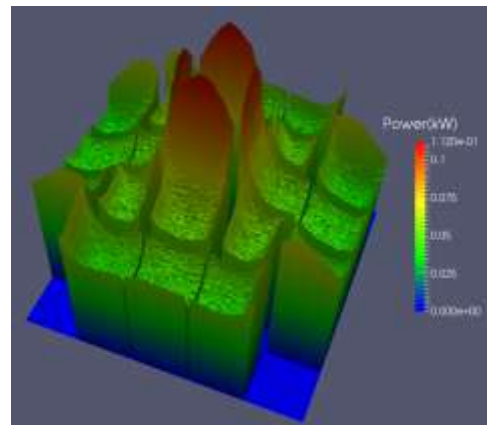


FIG. 4. Power distribution per plate of fuel elements

Figure 1 shows the hexagonal lattice reactor core, using standard TRIGA fuel elements. Figure 2 shows the reactor core size has not changed, and at the core of the new lattice is filled with plate-type fuel elements, so that the core lattice size of 5 x 5. The reactor core is surrounded by a graphite reflector that already exists. Number of lattices that can be loaded fuel elements including control elements as many as 21 positions. But the position of the C-3 will be used as an irradiation facility, known as a CIP, so that the number of fuel elements positions including the control elements positions is reduced to 20 positions. In Figure 2 does not appear that the position of A-1, A-5, E-1 and E-5 will be used as an IP.

Figure 3 shows that the highest power or the hottest fuel element on the B-2, C-3, C-4 and D-3 position, so that the thermo-hydraulic system design of the reactor core in this position should receive sufficient cooling. In addition Figure 4 shows the distribution of the power of each plate at each fuel element. From the figure it can be concluded that the lattice at position C-3 has a very high neutron flux, so it is best used as an irradiation facility.

6. Conclusion of Study

The results of study and analysis from the viewpoint of neutronic that the Bandung TRIGA reactors can be designed and be operated by using plate-type fuel elements. The fuel elements to be used, such as those used in the reactor Serpong. Neutronic analysis will be used as a reference in the design of thermo-hydraulic system and the reactor coolant system. Expected at the end of the second year, the design of the neutronic and thermo-hydraulic reactor can be resolved.

Acknowledgement, our thanks to colleagues at the Center of Multipurpose Reactor - Serpong, Technology Center for Nuclear Reactor Safety - Serpong, Center for Nuclear Fuel Element and the Center for Science and Accelerator Technology – Yogyakarta for their support so that the Bandung TRIGA reactor conversion program can be implemented.

References

- [1] PRASETYO BASUKI, PUTRANTO ILHAM YAZID, ZAKI SUUD, Neutronic design of plate-type fuel conversion for Bandung TRIGA 2000 reactor, Indonesian Journal of Nuclear Science and Technology, Volume 15. No.2 August (2014) 69-80. (in Indonesia)
- [2] JATI SUSILO, ENDIAH PUDJIHASTUTI, Analysis of power peaking factor for RSG-GAS core using U_3Si_2 -Al 4.8 gU/cc density fuel with cadmium, Tri Dasa Mega - Journal of Nuclear Reactor Technology, Volume 12 No. 3 (2010) 171-180. (in Indonesia)
- [3] SUWARDI, Vibration analysis test fuel elements for nuclear reactors versatile GA Siwabessy core plate-type dispersion U_3Si_2 Al, National Seminar on Science and Technology Applications, 2008 - IST AKPRIND, Yogyakarta (2008) (in Indonesia)
- [4] SNOJ, LUKA, RAVNIK, MATJAZ, Power peaking in mixed TRIGA cores, Nuclear Engineering and Design, volume 238, (2008) 2473-2479.

- [5] JATI SUSILO, ROKHMADI, Analysis of silicide equilibrium reactivity for control of the RSG-GAS core with SRAC-CITATION. Proceedings of Meeting and Presentations of the Scientific Basic Research in Nuclear Science and Technology, July 10, 2007, Yogyakarta, (2007) 74-81 (in Indonesia)
- [6] T. H. NEWTON, JR., M. S. KAZIMI, E. E. PILAT, Development of a low-enriched-uranium core for the MIT reactor, Nuclear Science and Engineering, Volume 157, Number 3, November (2007) 264-279
- [7] BATAN-BANDUNG SAR TEAM, Final Analysis Safety Report Bandung TRIGA 2000 reactor, Revision-3, Bandung, (2006) (in Indonesia)
- [8] SUBEKTI, TUKIRAN. Analysis of the effect of the cooling channel width of the fuel at the RSG-GAS core, Physics Journal of the Indonesian Physical Society, Volume A (6). Publication March 26, (2005) (in Indonesia)