PIE TECHNIQUE FOR HIGH DENSITY U3Si2-Al FUEL PLATE

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ABSTRACT

Techniques or methods of post-irradiation examination of nuclear fuel in the hot cell laboratory facilities are intimately associated with the fuel sample preparation, before the fuel sample were irradiated in reactor and tested in the hot cells. For testing of nuclear fuel U3Si2-Al plate type with a density of 4.8 g U / cc in hot cells after irradiation in the reactor, we have a different technique. With this technique we can simplify the process of dismantling the fuel bundle inside the hot cell to take a fuel plate from a fuel bundle for testing. With this technique we can irradiate some samples of the fuel plates simultaneously for a variety of different burn up easily and quickly, so that it can perform post-irradiation test quickly. With this technique we can also make the process of transfer of nuclear fuel from research reactors to hot laboratory cell with ease. We will describe the process of preparing multiple samples of fuel U3Si-Al plate type for irradiated in the reactor and tested in the hot cell. This is part of a post-irradiation test techniques conducted in the hot cell.

Introduction

Indonesia has three research reactors, two TRIGA reactors with UZrH fuel and a multipurpose reactor pool type with U3Si2-Al fuel and the density is 2.96 g U / cc. Two of the TRIGA reactors are located respectively in Bandung (called by name Bandung TRIGA reactor with a power capacity of 2 MW), and in Jogjakarta (called by name KARTINI reactor with a power capacity of 200 KW). Bandung TRIGA reactor was built in 1960, achieved first criticality in October 10, 1964 and officially opened in February 20, 1965.[1] Current status is now in the extension of the operating license. While KARTINI reactor was built in 1974, achieved first criticality in January 25, 1979 and inaugurated on March 1, 1979.[2] Current status is still in operation with a capacity of 100 KW. The third reactor is multipurpose reactor, located in Serpong with a power capacity of 30 MW named RSG-GAS was built in 1983, achieved first criticality in March 27, 1987 and officially opened in August 20, 1987, operated with full power is achieved in March 1992.[3] The status is now operation by power of 15 MW. Before conversion is conducted to silicide fuel, initially RSG-GAS reactor operates by using oxide fuel with a density of 2.96 g U / cc. [4] Current Status, RSG-GAS reactor operates by using fuel U3Si2-Al with the density of 2.96 g U / cc. BATAN (National Nuclear Energy Agency) continues to develop silicide fuel to increase its density. Silicide fuel development in BATAN has started since 1988 began with a density of 2.96 g U / cc, and research is continued begin to develop U3Si2-Al fuel with the density of 4.8 and 5.2 g U/ cc. [5,6,7]

To support the operation of RSG-GAS reactor, U3Si2-Al fuel with the density of 2.96 g U / cc is produced by the State company PT BATAN Teknologi now change its name to PT INUKI. To develop fabrication capabilities, it has been developed U3Si2-Al fuel high density. For the purposes of R & D, PT BATAN Teknologi has cooperation with BATAN to develop U3Si2-Al fuel high density. Through research cooperation between BATAN and PT INUKI, it has successfully fabricated U3Si2-Al fuel with the density of 4.8 g U / cc and 5.2 g U / cc. U3Si2 - Al fuel density of 4.8 GU / cc has been completed irradiated in the RSG-GAS. In this paper we would like to explain the technique of irradiation of fuel density of 4.8 g U / cc when irradiated in the reactor RSG-GAS for various levels of burn up. Post irradiation examination greatly influenced by sample preparation and technique of irradiation in a reactor. We will also outline in general how the fuel is to be fabricated.

Methodology

Sample to be post-irradiation tested is the fuel plate U3Si2 Al with the density of 4.8 g U / cc. The fuel is irradiated in a reactor with the burn up variation of 20%, 40% and 60%. Therefore, it has been fabricated 3 plate fuel elements U3Si2-Al with the density of 4.8 g U / cc. Three plates fuel elements U3Si2-Al with the density of 4.8 g U / cc is assembled in a bundle of fuel elements. The shape of the fuel bundle elements is the same as a bundle fuel element used in the operation of RSG-GAS reactor. One bundle of fuel element consist of 21 plates fuel elements as shown in Figure 1. The method for fabricating a bundle of fuel elements U3Si2-Al with a high density of 4.8 g U / cc, exactly the same as the method of fabricating a bundle of fuel elements U3Si2-Al with the density of 2.96 g U / cc which is used routinely to operate the RSG-GAS reactor. Safety analysis of the sample in the fabrication steps and irradiation have been considered properly.[8,9]

Fabrication of U3Si2-Al test fuel elements with the density of 4.8 g U / cc

Fuel fabrication process of U3Si2-Al with the density of 4.8 g U / cc is preceded with synthesizing U3Si2 ingot through smelting a mixture of metallic uranium with enrichment of 19.89% U-235 and high purity silicon metal with a composition by weight of 92.5% and 7, 5%. U3Si2 ingot produced from smelting then made into U3Si2 powder by mechanical treatment (by Ring mill and ball mill). U3Si2 powder which has met qualification as fuel dispersion then mixed with Al powder to make a core fuel element. The weight ratio of the powder mixture of U3Si2 and Al is determined based on the results of powder analysis of U3Si2 and Al, core fuel element dimension and density of the fuel to be fabricated. The next process, core fuel element is wrapped with frame and cover plate made of AlMg2, and formed into fuel plate element with hot rolling. Fuel plate element that have passed the test are assembled into test fuel element U3Si2-Al for irradiation test in the RSG-GAS reactor. Process flow diagram is shown in Figure 1.

Test Fuel Element U3Si2-Al with a density of 4.8 g U / cc composed of 21 plates with the composition of 18 fuel element plates dummy and 3 fuel element plate U3Si2-Al having a density of 4.8 g U / cc. Three fuel element plates U3Si2-Al are assembled on a plot number 3, 7 and 19 by inserting into the existing grooves on the two side plates, while 18 plates fuel elements dummy are assembled with swagroll technique. Pictures of test fuel elements U3Si2-Al is shown in Figures 2, 3 and 4.

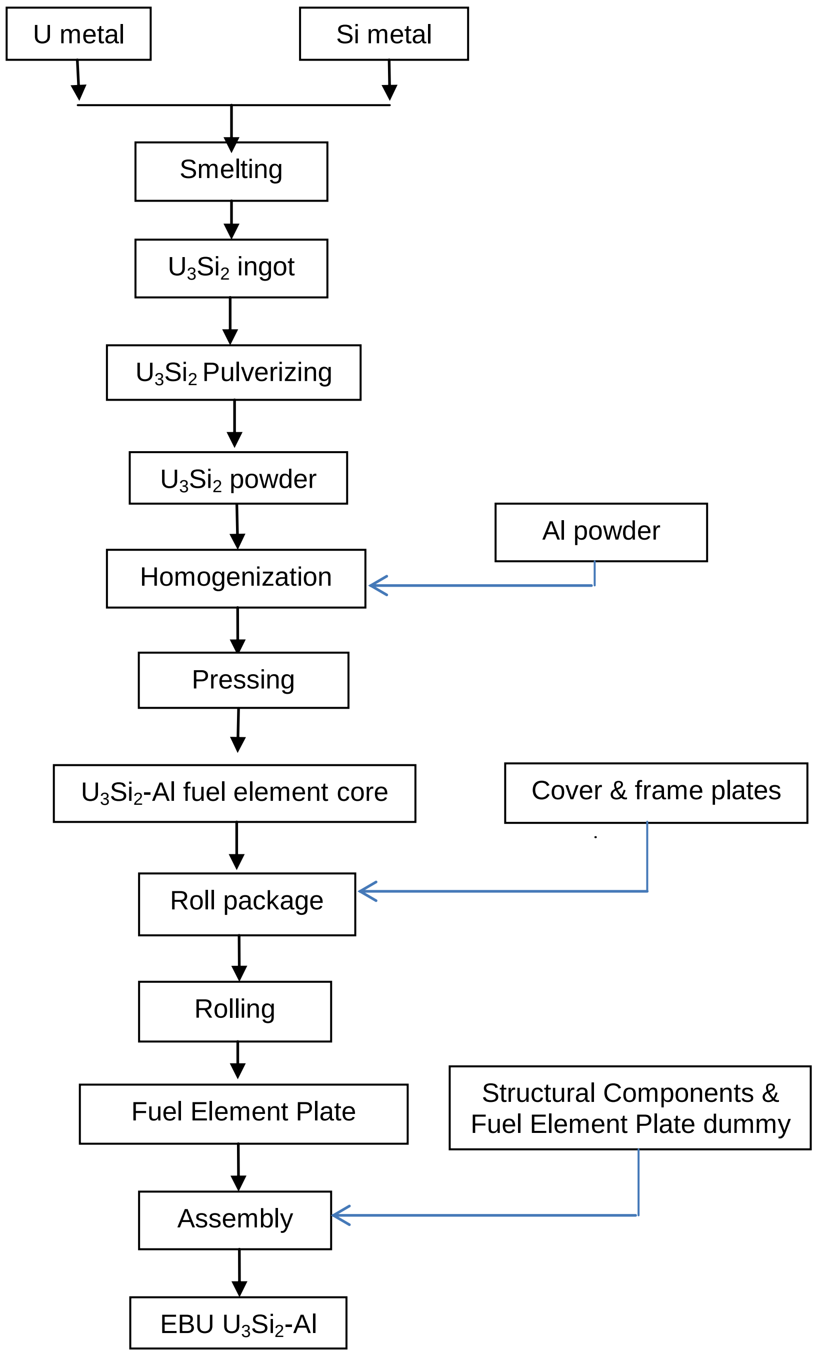

Figure 1. Process flow diagram

Testing / analysis performed on each stage of the process include:

- Powder analysis of U3Si2 fuel
- The content of uranium and impurities
- The size distribution of powder
- Powder density
- Analysis of aluminum powder

- Analysis of aluminum alloys
- Measurements / weight calculation of U and U235 in the test fuel element
- U distribution measurement in meat of fuel element plate
- Cladding thickness measurement
- Connective strength test for swag roll specimen
- Measurement on dimensions and cooling gap of test fuel element

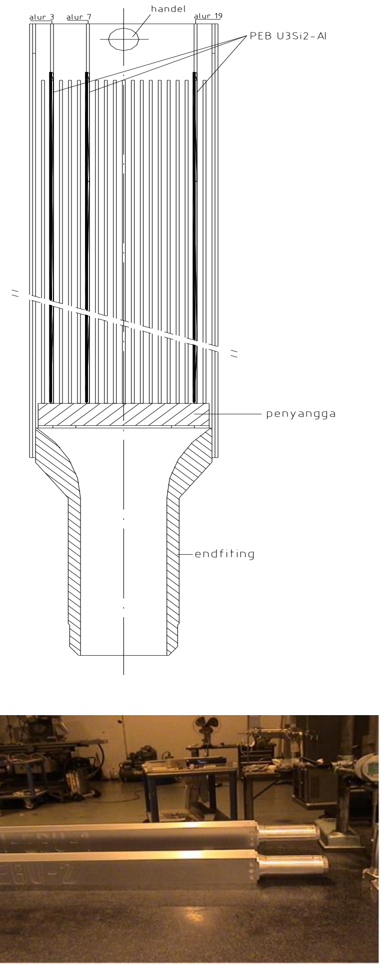

Figure 2. Test Fuel Element U_3Si_2-Al density 4.8 g U/cc.

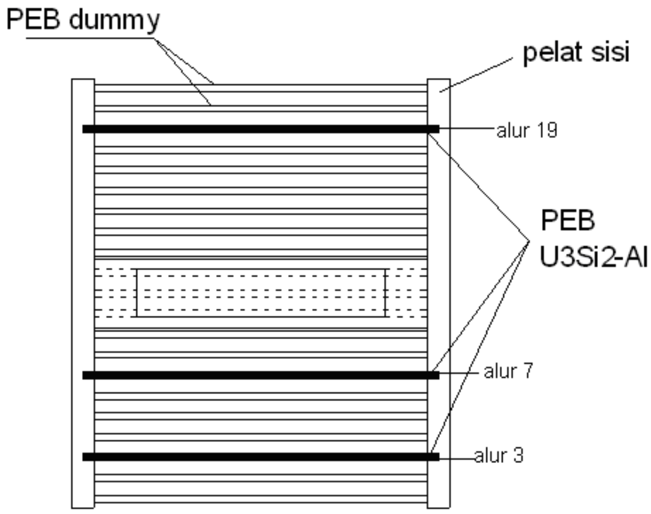

Figure 3. Top view of Test Fuel Element U_3Si_2-Al density 4.8 g U/cc

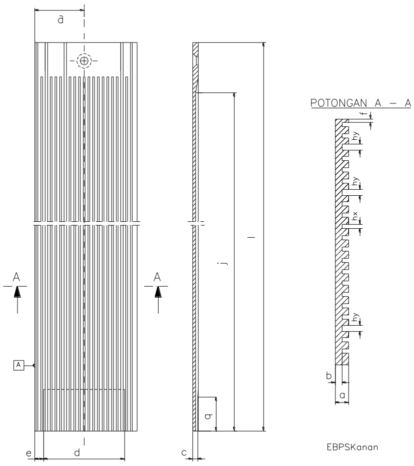

Figure 4. Side plate of Test Fuel Element density 4.8 g U/cc

Irradiation Prosedure

Prepare a Test Fuel Elements (TFE) U3Si2-Al, called RI-EBU 1, containing 3 Plate Fuel Elements (PFE) U3Si2-Al with a density of 4.8 g U / cc. PFE U3Si2-Al in TFE assembled in the groove of side plate number 3, 7 and 19 by inserting. The assembly is as follows:

RI-EBU 1 Assembly

No	PFE Code	Density, g U/cc	PFE possition in the side plate
1	CBBJ 249	4,80	Groove No.3
2	CBBJ 250	4,80	Groove No.7
3	CBBJ 251	4,80	Groove No.19

Irradiation has been conducted to test fuel element with density of 4.8 g U/cc and the irradiation steps is as follows:

Irradiation phase I to reach burn up 20%

- Insert test fuel element RI-EBU 1 in the position of G-7 in reactor core.
- Irradiate in reactor at 15 MW power.
- After two cycles of reactor operation is completed, take RI-EBU 1 from the reactor core and then place it on a shelf bridge in the reactor pool.
- Take PFE CBBJ 249 (groove No. 3) in the RI-EBU 1 then insert the PFE in the container to move the PFE to transfer casks. Subsequently transferred PFE to the Radio-metallurgy Installation (IRM) hot cells for post irradiation test.
- Now, the groove No.3 in side plate is empty after not being filled with PFE code CBBJ 249 on RI-EBU 1, filled with a dummy PFE by means of insertion.
- PFE code CBBJ 249 was taken from the RI-EBU 1 by means of linking up with hook tool as shown in the Figure 5.

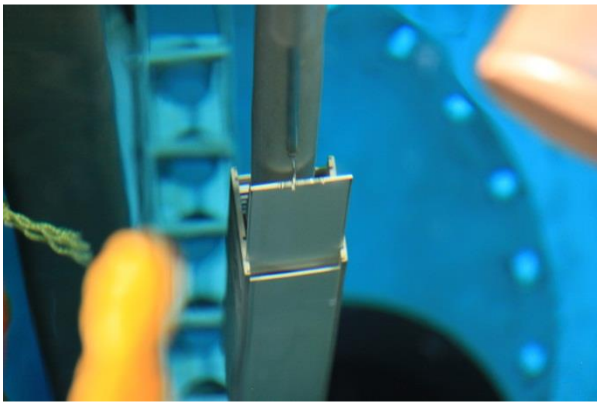

Figure 5. Withdrawal plate fuel elements in reactor pool

- Enter again RI-EBU 1 to the position of G-7 (irradiation position) in the reactor core.
- Irradiation was continued with the power of 15 MW for the next plate fuel element with the same method for 40 and 60 % burn up.

Discussion

Test fuel elements with a density of 4.8 g U / cc have been fabricated with the full size as fuel element used in the RSG-GAS reactor. In the fabrication there is only a slight modification in order to facilitate the testing. Test fuel element fabrication method is similar to the fabrication method of fuel element used in the routine production. There are only slight modifications in the stage of swag-roll process.

Three plates of fuel elements and 18 plates of dummy fuel elements are assembled in a test fuel element. Three plates of fuel elements are assembled by without doing swag-roll, just inserted into the groove in the two side plates of test fuel element. Three plates of fuel elements are each inserted into the groove numbers 3, 7 and 19.

The 18 plates of dummy fuel elements are assembled in a test fuel element by means of inserted into the groove in the two side plates of the test fuel element and performed swag-roll. Swag-roll is done by using a swag-roll machine with a clamping process along two side plates on both sides of the plate width of the dummy fuel elements. This swag-roll process follows the production procedure which is routinely performed.

While the three plates to be irradiated fuel element in the RSG-GAS reactor is not subject swag-roll just inserted along two side plates. Wide groove in the side plates for the insertion of the fuel element plate slightly widened from 1.43 normal size mm to 2.00 mm, making them easier to insert and take out the plate fuel elements from the existing test fuel element in the reactor pool. Three plates of the fuel element have a size longer than the normal size. The size is extended approximately 40 mm, so that it is easier to take the plate fuel elements from the existing test fuel element in the reactor pool. At the top of the 3 plates fuel elements, each fitted with wire to make it easier in the process of taking plates fuel elements from the existing test fuel element in the reactor pool. See Figure 6.

Figure 6. Wire in the top of plate fuel element

Three plates fuel elements with U density of 4.8 g / cc has been irradiated safely with burn-up up to 60%. So, the techniques or methods of post-irradiation examination of nuclear fuel in the hot cell laboratory facilities are intimately associated with the fuel sample preparation, before the fuel sample were irradiated in reactor and tested in the hot cells. For testing of nuclear fuel U3Si2-Al plate type with a density of 4.8 g U / cc in hot cells after irradiation in the reactor, we have a different technique as explained above. With this technique we do not need the process of dismantling of the fuel bundle inside the hot cell to take a fuel plate from a fuel bundle for testing. With this technique we can irradiate some samples of the fuel plates simultaneously for a variety of different burn up easily and quickly, so that it can perform post-irradiation test quickly. With this technique we can also make the process of transfer of nuclear fuel from research reactors to hot laboratory cell with ease.

So, the advantage of this techniques or method is that it can speed up the process of irradiation further because it does not need to perform the process of moving the fuel bundle from the reactor into the hot cell facility. We just need to move the fuel plate not fuel bundle. The process of removal of fuel plate from RSG-GAS reactor to hot cells of Radiometallurgy Installation is usually done with a transfer channel through the underground, or using transfer casks to move fuel from the reactor building to the hot cell laboratory IRM as shown in Figure 7. Both the process is quite time consuming.

Figure 7. Process transfer of fuel plate with transfer cask.

In this technique also does not need to perform the process of dismantling the fuel bundle inside the hot cell (Figure 8), where the process is quite long. By not doing dismantling bundle of fuel in hot cells also can reduce fuel waste cutting results in hot cells.

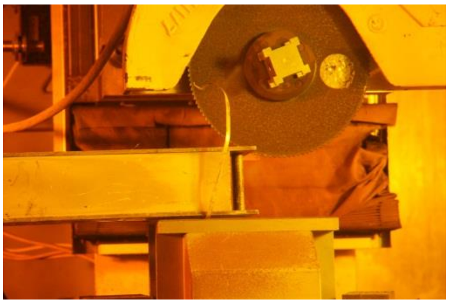

Figure 8. Process of dismantling fuel bundle [10]

Conclussion

- Techniques or methods of post-irradiation examination of nuclear fuel in the hot cell laboratory facilities are intimately associated with the fuel sample preparation, before the fuel sample were irradiated in reactor and tested in the hot cells.
- For testing of nuclear fuel U3Si2-Al plate type with a density of 4.8 g U / cc in hot cells after irradiation in the reactor, we do not use roll swag in the fabrication of fuel elements bundle.
- With slightly modifications in the fabrication of fuel elements, we can remove the fuel elements from the bundle of fuel inside the reactor pool.
- With this technique we do not need the process of dismantling of the fuel bundle inside the hot cell to take a fuel plate from a fuel bundle for testing.
- With this technique we can irradiate some samples of the fuel plates simultaneously for a variety of different burn up easily and quickly, so that it can perform post-irradiation test quickly.
- With this technique we can also make the process of transfer of nuclear fuel from research reactors to hot laboratory cell with ease.
- By not doing dismantling bundle of fuel in hot cells also can reduce fuel waste cutting results in hot cells.

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