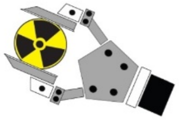

Non destructive test nuclear fuel U_3Si_2/Al 4,8 g U/cm^3 post irradiation with 60% burn up research reactor

Yusuf Nampira, Sri Ismarwanti, Helmi Fauzi, Kawkab Mustopa

Center for Nuclear Fuel Technology-BATAN, Building No 20 Puspiptek Area, Serpong, Tangerang-Selatan, Banten 15310 - Indonesia

Annual Meeting Hot Laboratories and Remote Handling

HOTLAB 2016

October 2 – 6, 2016
Karlsruhe, Germany

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RMI
Radiometallurgi Installation

OUTLINE

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- Nuclear Development (Facility)
- Irradiation Technique
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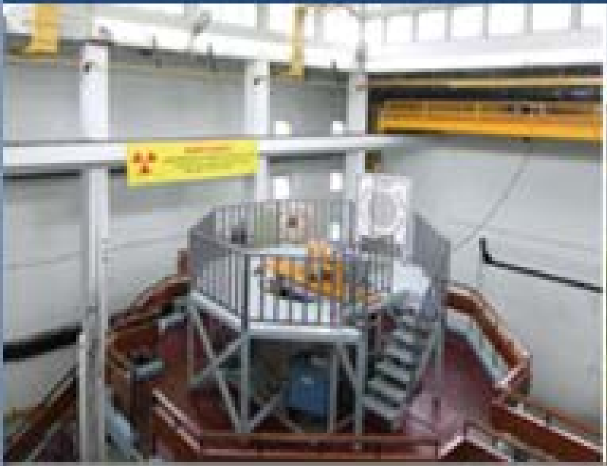
- Discussion
- Conclusion

INTRODUCTION

INTRODUCTION

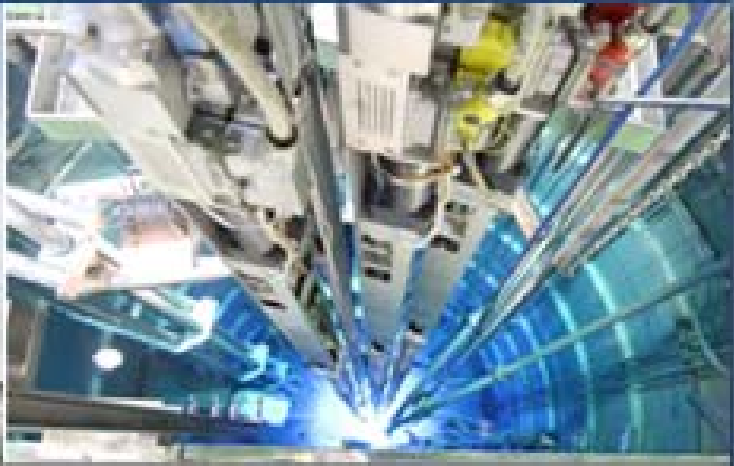


Triga 2000 Reactor

- Location: Bandung
- Operated on1964 with 250 kW thermal power capacity
- Power upgrade into 2000 kW, on the year of 2000
- Function: Research & Isotope Production

Kartini Reactor

- Location: Yogyakarta
- Operated on 1979
- 100 kW Thermal power capacity
- Function : Research and human resource training facility



RSG G.A Siwabessy

- Location : Serpong, Tangerang
- Operated on 1987
- 30 MW Thermal power capacity
- Function : research, isotope production and materials research

Nuclear fuel development

- RSG reactor having purpose production of radiopharmaceutical and nuclear material testing
- For effective reactor operation we have development program with increasing density of uranium (from 2.96 g U/ cm^3 to 4.80 g U/ cm^3) low-enriched uranium 19.70%.
- For study overview of performance nuclear fuel material (plate type) we have plan varying burn – up 20 %, 40 % and 60 %.
- Non Destructive Test (NDT) is a important part in the PIE to obtain preliminary approach to narrow observation area degradation of fuel elements after irradiation.

Nuclear fuel development

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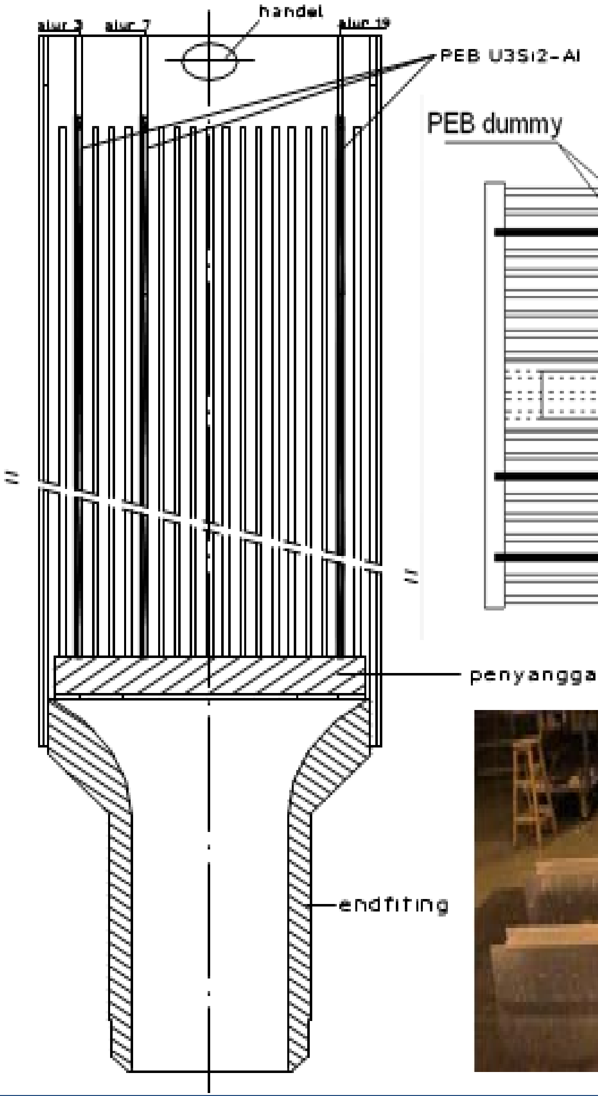


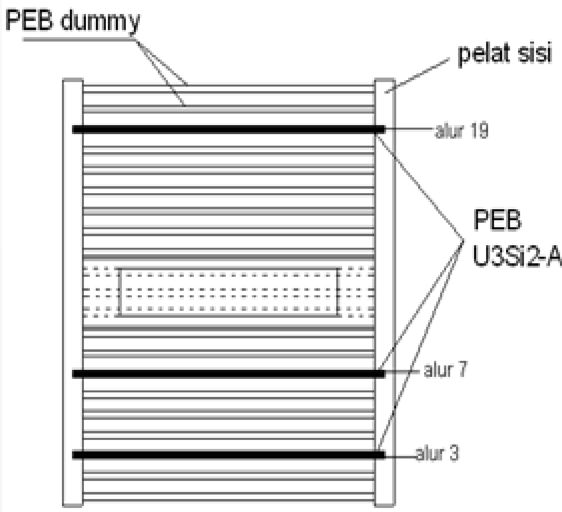


Table 1. Fuel plates element specifications U_3Si_2/al uranium loading level 4,8 gU/cm^3

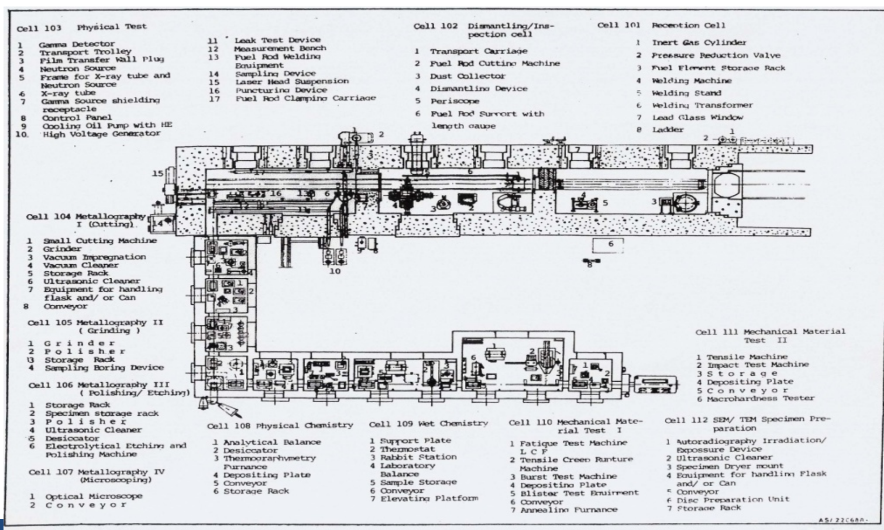
Clasification	Value
Enrichment ^{235}U	$19.75^{+0.2\%}$ & $19.75_{-0.5\%}$
Number of fuel element in 1 bundle	3 Fuel element
Composition ^{235}U / fuel element	18,36 ± 0,30 g
Composition ^{235}U / bundle	55,08 ± 3,80 g
Zona 1 tolerance	nominal ± 20 %
Zona 2 tolerance	nominal + 25 %

Table 2. Dimension measurement data

No	Kode Fuel	Length,mm	Width,mm	High,mm
1	CBBJ 249 (3)	629,00	70,70	1,40
2	CBBJ 250 (7)	629,00	70,71	1,39
3	CBBJ 251(19)	629,00	70,70	1,39

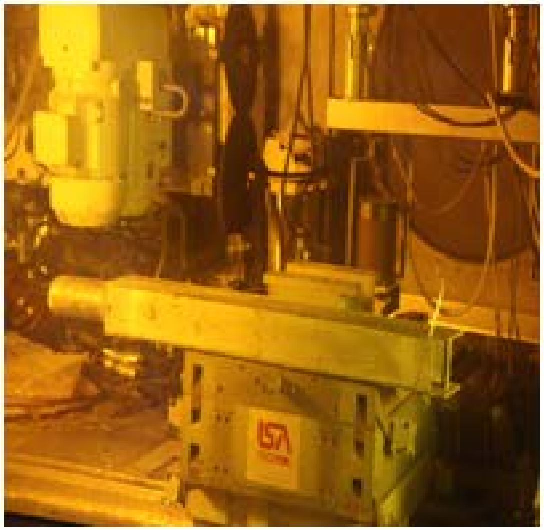
Hot laboratory

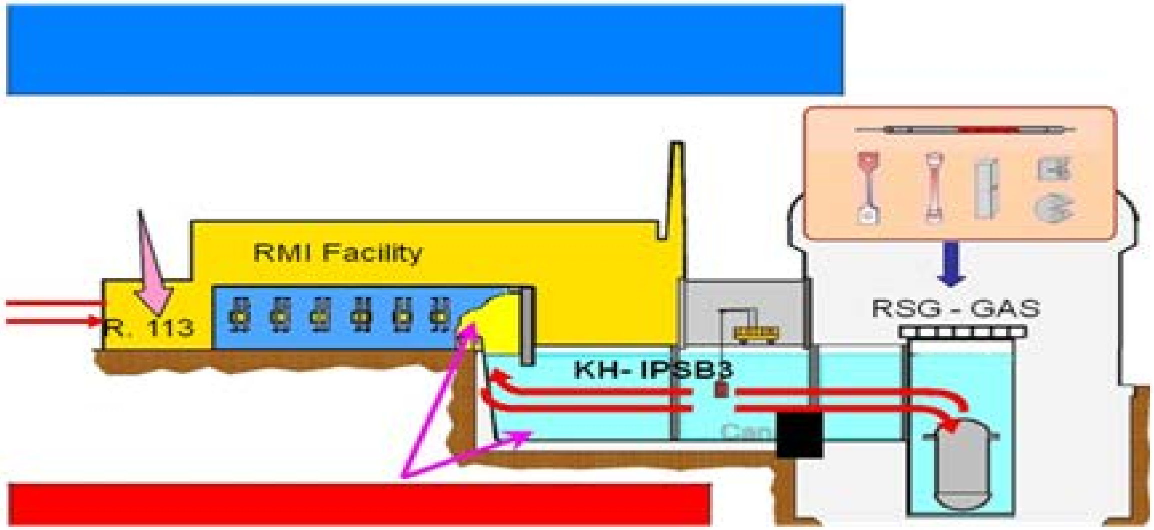
- RMI Hot laboratory was commissioned in 1989. One of its functions is to Handle fuel element PIE from research reactor and power reactor, and other reactor component. The PIE facilities had been used to examine fuel element And low enriched uranium (LEU) foil targets.
- 14 Hotcells (3 large concrete cells, 9 steel cells cubilcles arranged In U- shape, surrounding the central rear service area & 2 basement waste cells underneath) . 34 units of manipulators, 1 unit of power manipulator and 5 units of incell cranes to handle the work equipment inside the hot cells; and transfer among hot cells is done using two conveyor lines.



HOT CELL LAY OUT FLOOR PLAN

Experimental Procedure

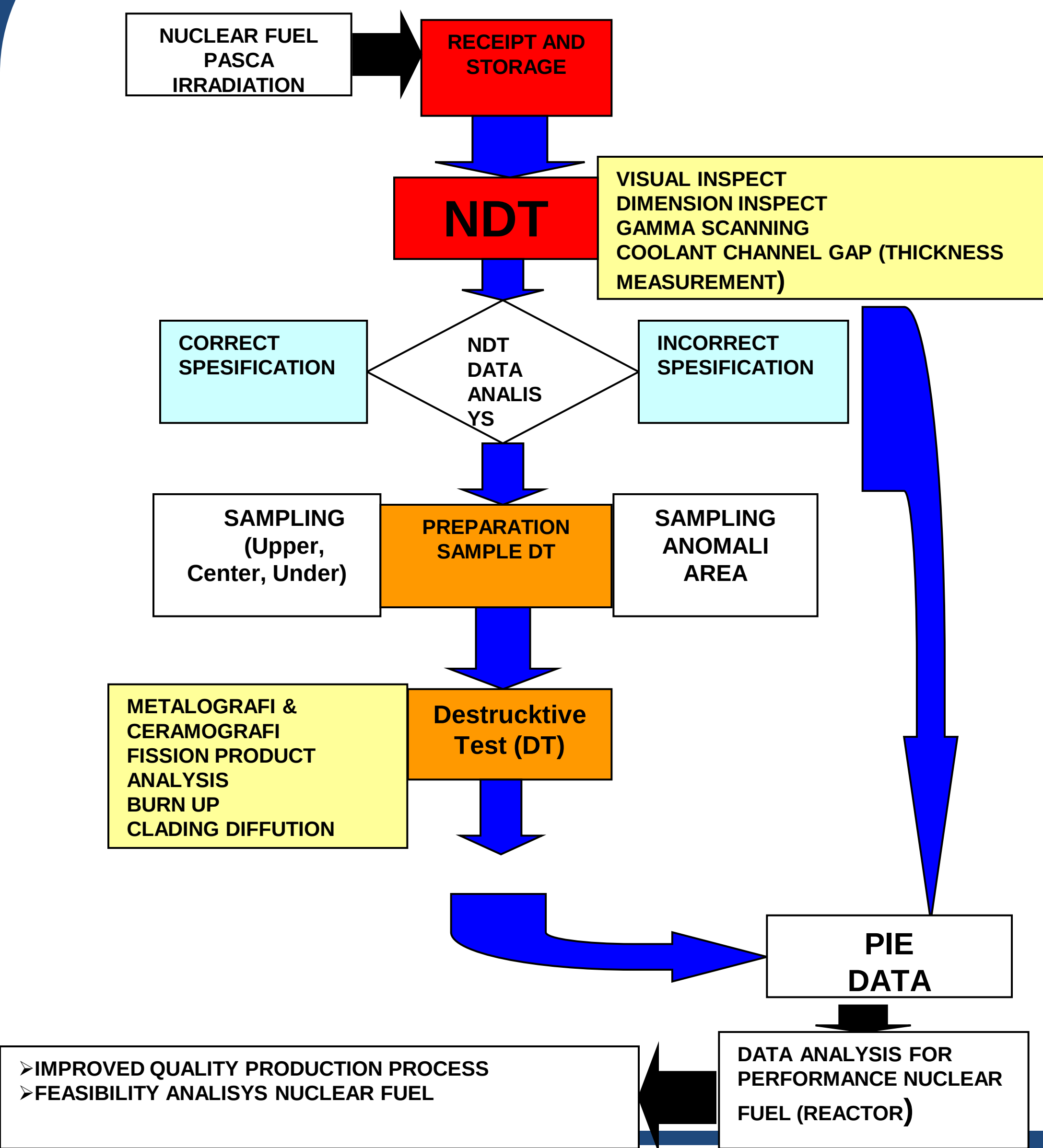




- Nuclear Fuel U_3Si_2/Al uranium loading level 4,8 g U / cm^3 were supplied by PT. INUKI (Persero) nuclear industry of indonesia and irradiated in the core reactor G.A Siwabessy with varying burn – up.

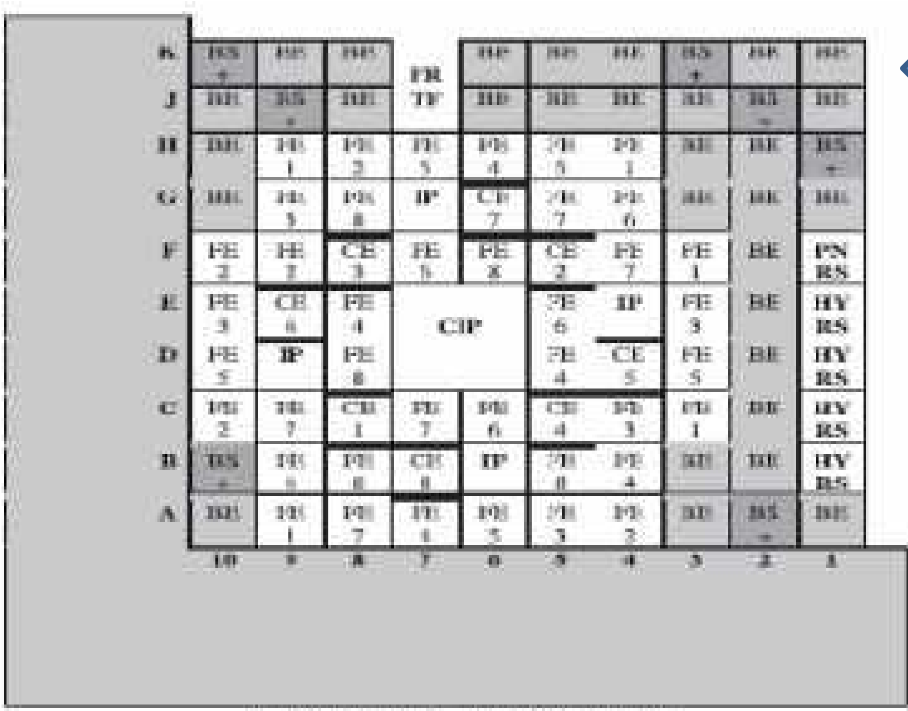
- After cooling more than 101 days, the sample was tranferred to hot laboratory RMI – facility using canal channel.

Experimental Procedure



The experiments conducted are visual observation using binoculars Nikon and digital cameras DLSR Canon 50D then Measurement plate thickness fuel elements each performed at 5-positions on the direction of the long plate and 3-position measurement in the direction of the width plate using a thickness gage Mitutoyo and the last, Scanning gamma rays done at a distance of 5 mm each variation with time of enumeration 500 seconds for 20% -burn up, 300 seconds for 40%-burn up and 200 seconds for 60% using a gamma spectrometer ORTEC with liquid nitrogen as a cooling high purity germanium detector (HpGe), ^{60}Co as standards for energy calibration and ^{152}Eu as standards for detector efficiency calibration

Irradiation Technique



BERYLLIUM BLOCK REFLECTOR

Fuel Elements (FE), Control Element (CE), Be reflector element (BE), Be reflector element with plug (BS +), Irradiation Position (IP) , Central Irradiation Position (CIP), Pneumatic Rabbit System (PNRs), Hydraulic Rabbit system (HYRS)

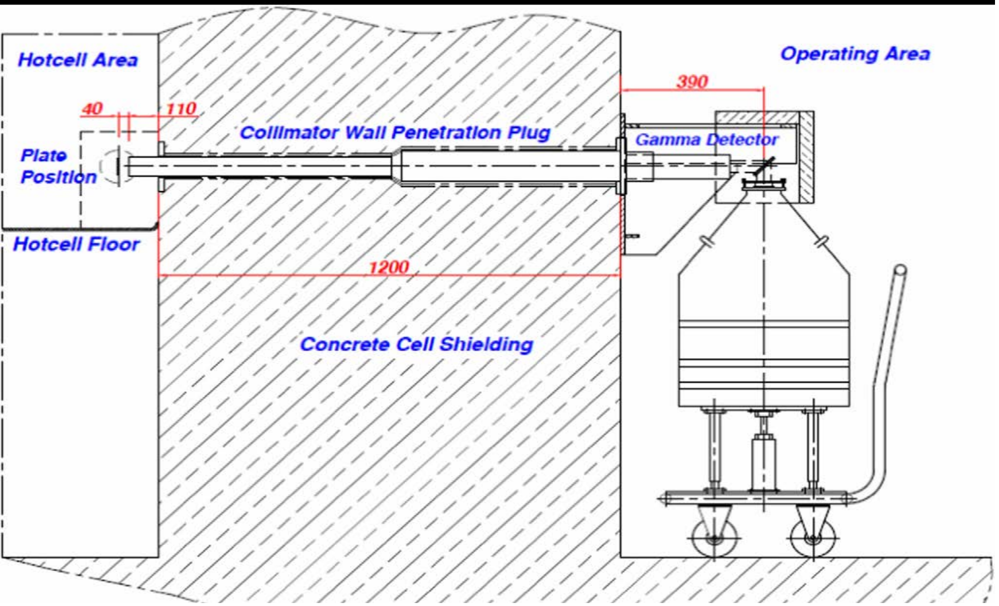
- RI-EBU 1 : Three plate fuel element U3Si2-Al 4,8 g U / cm^3 are assembled in test fuel element into the groove of side plate No 3 (CBBJ 249), 7 (CBBJ 250) and 19 (CBBJ 251) with 15 MW power reactor in the G7 or IP position.

No	Fuel Code	Time Duration	Burn - Up
1	CBBJ 249	6 Month	20 %
2	CBBJ 250	18 Month	60%
3	CBBJ 251	12 Month	40 %

Discussion

Gamma-scanning

[redacted]



Tabel 3. Radionuclide ^{134}Cs dan ^{137}Cs spesification

Isotope	$T_{1/2}$ (year)	σ (barn)	E (keV)	% yields
^{134}Cs	2,1	24,3	605	0,976
^{137}Cs	30,1	0,05	662	0, 851

- Distribution of atomic fission reaction done by measuring fission product that is used as an indicator of the fraction of fuel. Radionuclide selection considerations are:

1. Radionuclide that has high *fission yield* of the fission reaction ^{235}U
2. Have small neutron uptake.
3. Have a long radioactive half-life.

Discussion

Gamma-scanning

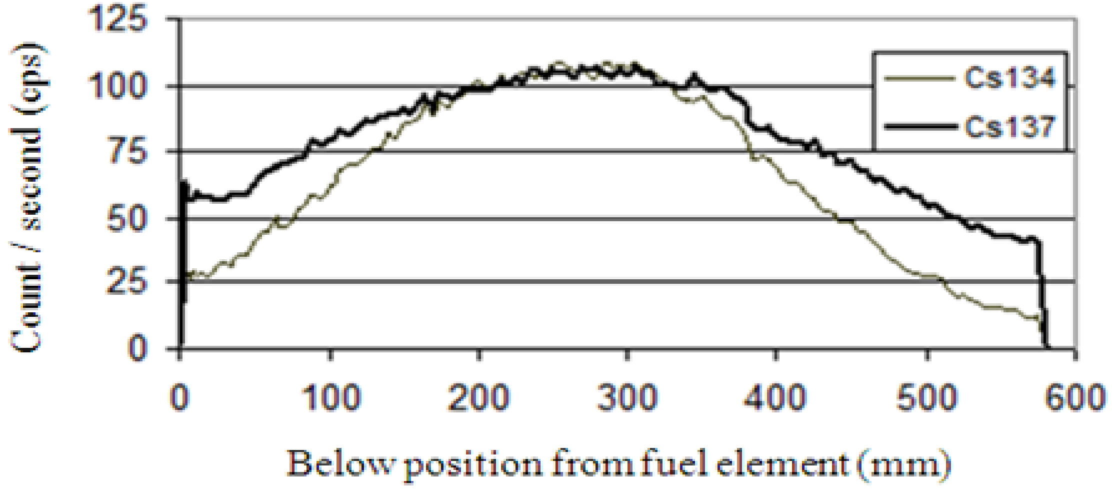


Figure 3. Distribution pattern ^{134}Cs dan ^{137}Cs nuclear fuel U_3Si_2/al uranium loading level 4.8 g/cm^3 with 40% theoretical burn-up.

Results of scanning energy gamma peaks at 605 keV (^{134}Cs) and 662 keV (^{137}Cs) in various positions on the plate element uranium silicide fuel ^{235}U yield of 20% and 40% burn-up, as shown in figure. 3. Distribution of ^{134}Cs and ^{137}Cs in uranium silicide fuel element plate loading level of 4.8 g / cm^3 follows a normal distribution pattern.

Discussion

Gamma-scanning

$$F_{i,j} = \frac{A_{i,j}}{A_{i,r}} F_{i,r}$$

F i, j : Fraction of fuel calculation position j on the plate i
F i, r : Fraction of mean fuel on a plate i
A i, j : Activity cesium in position j on the plate i
A i, r : Activity of mean cesium on a plate i

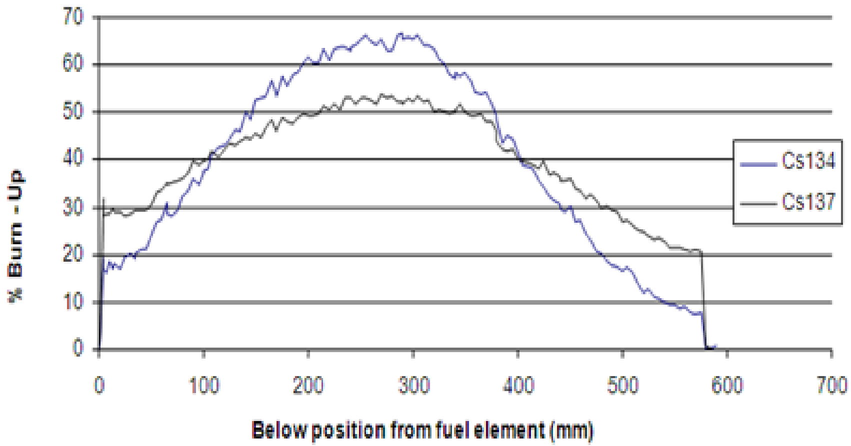
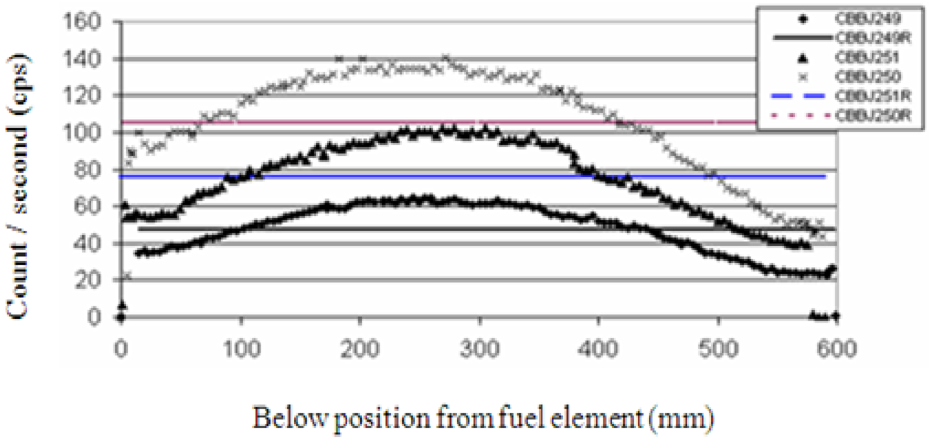


Figure 4. Distribution pattern burn-up nuclear fuel U_3Si_2/al uranium loading level 4,8 g/cm^3 with 40% experimental burn-up.

Calculation of fractions at each location based on measurements of ^{137}Cs showed that the maximum burn-up in the fuel is in the region between 235 mm to 345 mm with a value of 52.7% ^{235}U burn-up, while based on the measurement of cesium-134 burn-up area is located at 250 mm up to 320 mm from the bottom of the fuel, with a value of 66.14% ^{235}U burn-up (Fig. 4). Maximum difference in burn-up is caused by differences in ^{137}Cs source of fission ^{235}U, ^{137}Cs decays more slowly in comparison with ^{134}Cs. In addition, absorption value of neutrons for ^{134}Cs are greater than ^{137}Cs.

Discussion

Gamma-scanning



CBBJ249 & CBBJ 251

CBBJ : 60% burnp-up

Figure 5. Distribution pattern ^{134}Cs dan ^{137}Cs nuclear fuel U_3Si_2/al uranium loading level 4,8 g/cm^3 with 60% experimental burn-up.

Tabel 4. 60 % bum up value nuclear fuel U_3Si_2/al uranium loading level 4,8 g/cm^3

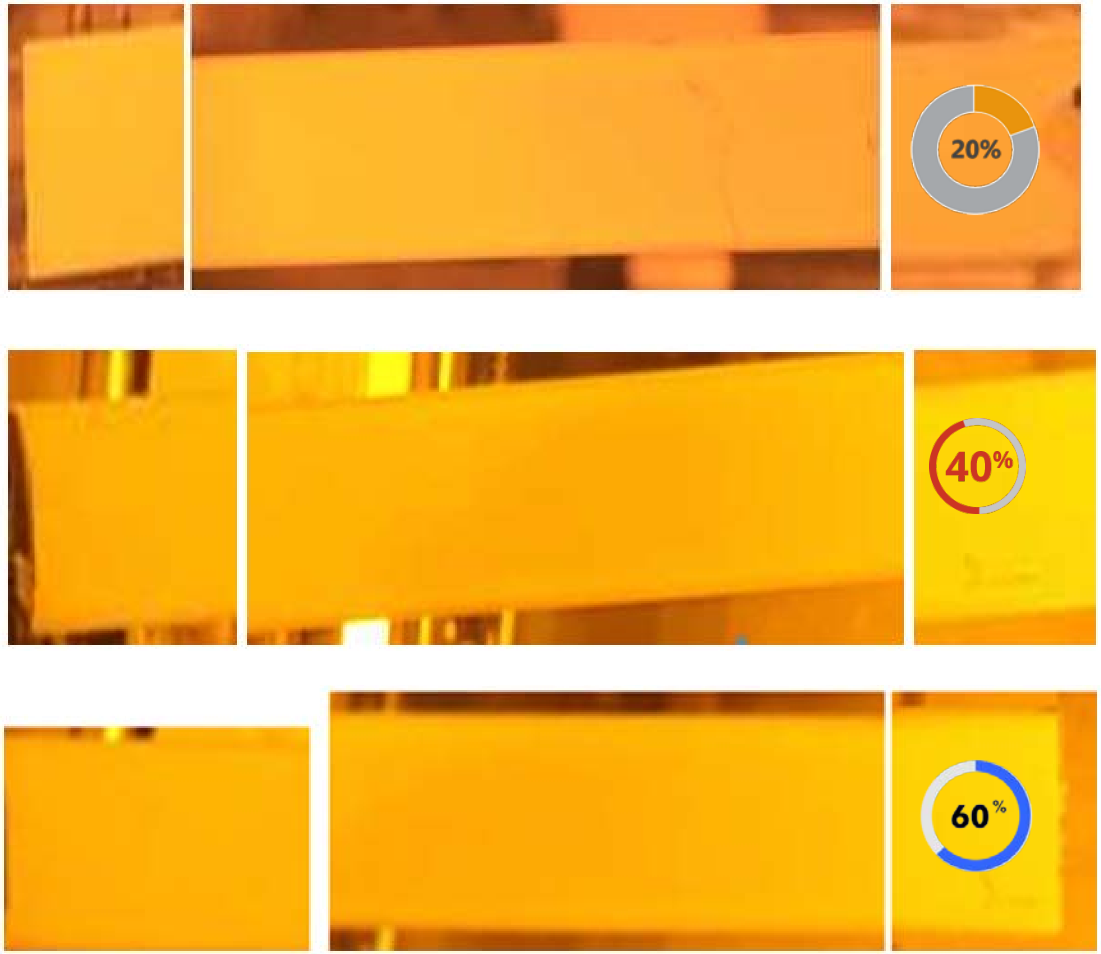
Measurement position (from below) (mm)	Burn Up Measurement (% ^{235}U)
582.5	26.65
250	76.35
6.25	47.52

Based on the circumstances mentioned above burn-up data from ^{137}Cs, and for maximum 60 % burn up in the fuel region between 250 mm to 300 mm are shown in table.

Test results show that the burn-up distribution of ^{235}U in the fuel plate follows a polynomial rank 3 pattern. The middle part of the fuel element reaching 77% burn-up, swelling plate fuel element is very small (less than 1%)

Discussion

Visual Observation



Cladding surface of the plates have been homogenously oxidized and do not indicate oxidation pitting on the surface. Surface oxidation doesn't show any noticeable color differences in the loading area due to overheating as a result of the nuclear reactions in the fuel. The surface oxidation is in the normal range for a plate type fuel element cladding.

Discussion

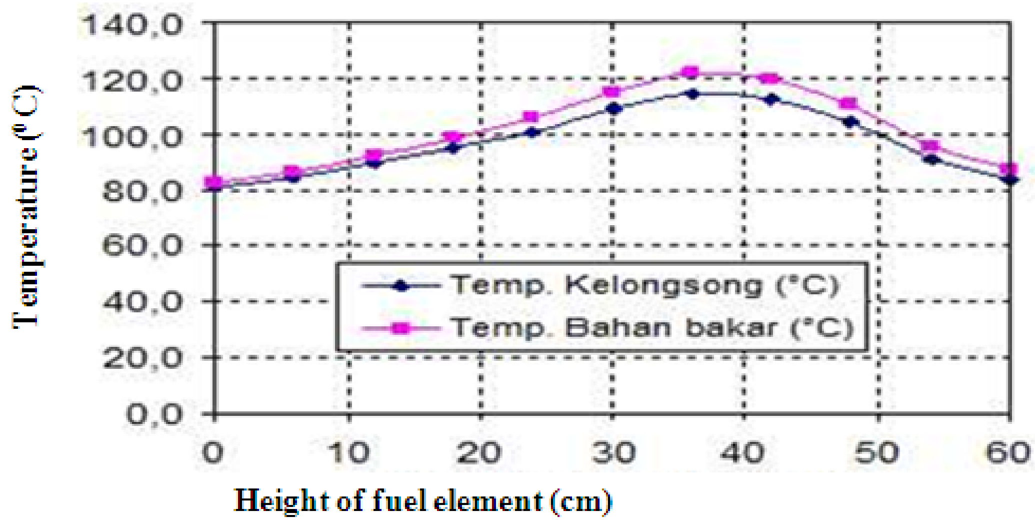


Figure 9. Distribution heat pattern of fuel element and cladding nuclear fuel U_3Si_2/al uranium loading level 4,8 g/cm^3.

Based on the calculation of the temperature of the fuel reactor in a steady state operating condition the heat distribution pattern is shown in figure. 9 where the temperature reached a maximum in the region from 30 cm until 40 cm from the bottom position of fuel element. Maximum difference between high and low temperature overall in the fuel is 40 ^{0}C, it is concluded that the corrosion effect on the surface fuel element (cladding AlMg) has relatively the same value.

Discussion

Measurement Thickness

Figure 9.1. Visual data thickness gauge nuclear fuel U_3Si_2/al uranium loading level 4.8 g/cm^3 with 20% burn-up post irradiation.

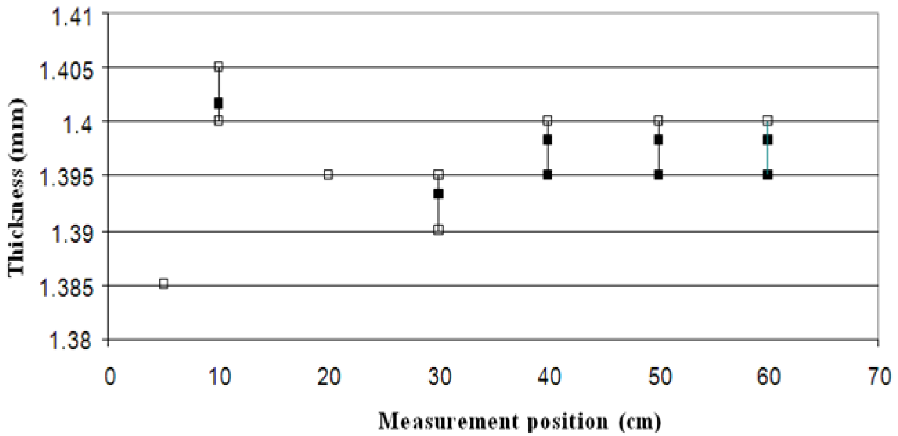


Figure 9.3. Fuel plate element 20% burn – up

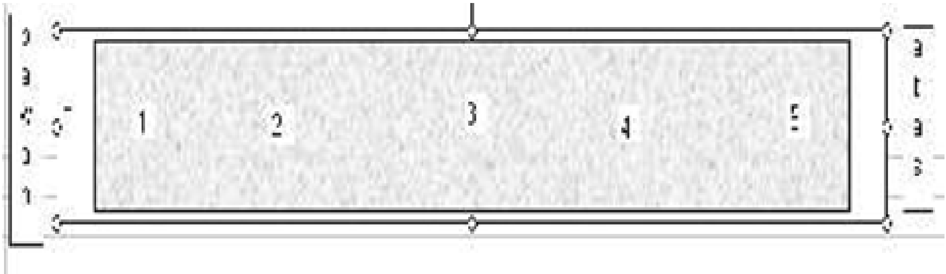


Figure 9.2. Measurement Position thickness of the fuel element

In accordance with the level of fission reactions that occur in the fuel, the <u>volume</u> will change constantly in accordance with burn-up achieved by the fuel.

Discussion

Measurement Thickness

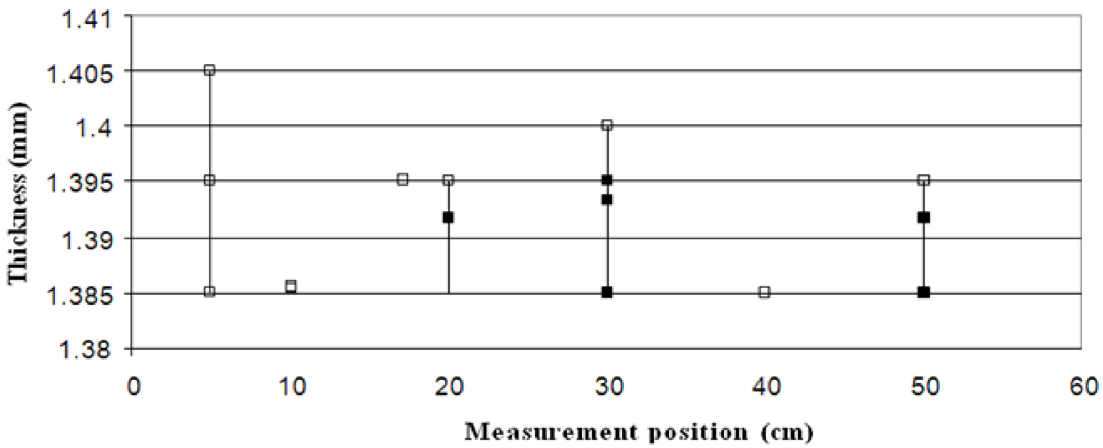


Figure 9.4. Fuel plate element 40% burn – up

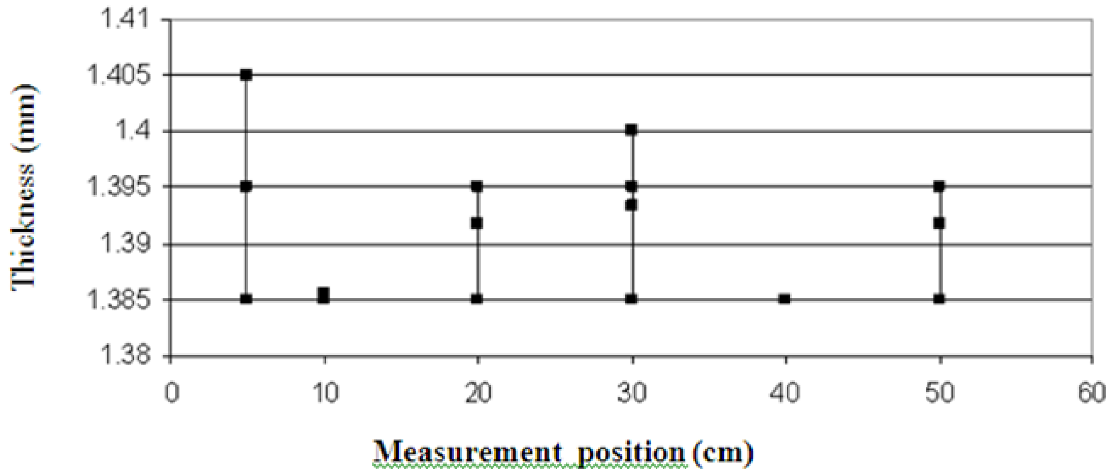
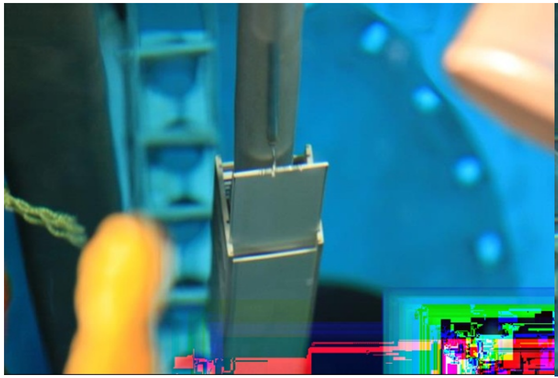


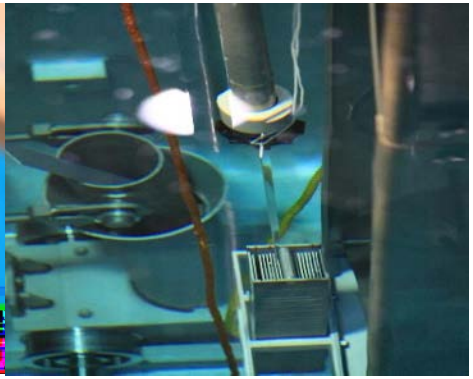
Figure 9.5. Fuel plate element 60% burn – up

The thickness value average after irradiation with 20%, 40% and 60% burn-up is between 1,385 mm to 1,405 mm compared to thickness before irradiation between 1.39 mm to 1.40 mm. Thus the thickness change is still within the permitted limits. (does not affect the flow of cooling water in the fuel bundle)

CONCLUSION

The Post Irradiation observations above show that: the plate uranium silicide fuel element / Al (U_3Si_2/Al) uranium loading level of 4.8 g / cm^3 after irradiation in the reactor core to achieve the theoretical average burn-up of 20% , 40% and 60% indicated distribution of burn-up in accordance with the normal distribution (in the middle of the fuel element with a burn-up of 60%, reaching a burn-up 77%), swelling plate fuel element is very small (less than 1%) and no corrosion which could potentially release uranium occurs on the fuel plate element.





Thank You

RMI

Radiometallurgy Installation

Addition